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OUR SECOND VOLUME.

The present issue, closing the second volume of this journal, is accompanied by the yearly index. We have tried to prepare the index with a great deal of care as to cross-references and general completeness; the idea has been that even the most useful technical information, when scattered throughout the columns of a periodical, must be considered as buried therein forever, if the index is not complete and handy. In comparison with our first volume, which covered 598 reading pages, our second volume is smaller in size, covering 518 reading pages. The reason is that the first volume was exceptional in extending over sixteen months, from September, 1902, to December, 1903, and thus containing sixteen numbers, while the present and our following volumes are running from January to December, thus containing twelve numbers. From the above figures, it will be seen that the reading matter of our first volume covered, in the average, thirty-seven pages per issue, in our second volume forty-three pages. This increase of about 15 per cent in the amount of reading matter furnished to our readers for the same price, is one instance of improvement that was aimed at, while a glance over our index will show, we hope, that we have been successful in covering the field so broadly and completely as to satisfy the needs of all interested in electrochemical and electrometallurgical developments and in any new and important advances made in chemistry and metallurgy in general.

THE CANADIAN COMMISSION REPORT ON EUROPEAN ELECTRIC IRON AND STEEL FURNACES.

In this number we publish a long abstract of the report issued in the first days of November by the Commission appointed by the Canadian Government to investigate and report upon the different electric furnace processes employed in the iron and steel industries, or in process of development in Italy, France and Sweden. Besides a voluminous appendix the report proper consists of three parts: First, the report of Dr. Eugene Haanel, Superintendent of Mines, and the head of the commission; second, the report of Mr. C. E. Brown, acting as the electrician; and third, the report of Mr. F. W. Harbord, the metallurgist of the commission. Summaries of the results of the investigation in form of conclusions are given by Dr. Haanel and Mr. Harbord. The report is certainly one of the most important publications ever issued by the Canadian Government. As a British contemporary puts it, it "stands a monument of legitimate government activity, directed with intelligence and achieving its goal." The goal of the work of the Commission was to establish facts as to the processes investigated. The report, therefore, as a whole, is chiefly descriptive. The Commission describes what they saw, the plants and the apparatus, many valuable photographs and drawings of the furnaces being included. They also describe

in great detail the original tests which they made in several cases, giving details of the raw materials used, the expenditure of energy, the output and the results of extended analyses and mechanical tests of the products. The plants visited by the Commission were Gysinge and Kotfors, Sweden; LaPraz, France; Turin, Italy; and Livet, France. Tests were conducted at Gysinge, LaPraz and Livet only. Practically all essential details of the description of plants and processes are known to the readers of this journal, for which the main point of interest, therefore, lies in the original tests made by the Commission. We need offer no apology for reporting on them, and especially on the extremely valuable metallurgical tests of Mr. Harbord, at unusual length. Those of our readers who want to look up the construction of one or the other furnace, should refer to the indices of our two volumes under *Furnace, Electric, Iron and Steel*. There is at least one electric furnace process—that of Girod—making special steels on a commercial scale not mentioned in the report.

In considering the results obtained in the tests of the Commission, we may first take up the preliminary question whether the electric furnace can be used to obtain from given raw materials the commercial products of the iron and steel industry. This question is answered completely in the affirmative by the tests of the Commission, as was to be expected. Steels of any composition can be obtained in electric furnaces of different designs. With respect to the smelting of iron ore, the tests show that the quality of the iron produced in the electric furnace depends upon maintaining the same conditions as in the blast furnace, the main difference being that electrical energy is used instead of combustion of carbon to produce the necessary temperature. The reactions in the electric furnace, as regards the reduction and combination of iron with silicon, sulphur, phosphorus and manganese, are similar to those taking place in the blast furnace. By altering the burden and regulating the temperature by varying the electric current, any grade of iron, gray or white, can be obtained and the change from one grade to another is effected more rapidly than in the blast furnace. However interesting these results are, they are of small importance compared with the fundamental commercial question of the cost of the electric furnace process. Any engineering problem has in the last end only one goal, that is to make as much money as possible. Considered from this point of view, careful distinction must be made between three main problems: First, the production of high-grade steels of crucible steel quality; second, the production of structural steel to compete with Bessemer and open-hearth steel; third, the reduction of iron ore to pig iron.

With respect to the manufacture of crucible steel, either in the induction furnace or in Héroult's and Keller's resistance furnaces, the conclusion reached by the Commission is that steel equal in all respects to the best Sheffield crucible steel, can be produced at a cost considerably less than with the old crucible process. The leading iron and steel journal of this country, in commenting editorially on this result, adds the following qualification: "But this is, of course, only the case where electric energy can be had cheaply." This statement does not seem to be well considered, and would probably not have been made had the writer analyzed the figures given in

Mr. Harbord's report upon which the conclusion is based. The fact is that the item of electrical energy is of comparatively small importance in this special problem. In the comparison of the cost of the electric furnace process and the crucible process for making crucible steel, we have to place essentially the cost of electrical energy and labor against the cost of fuel and labor in pot melting. The chief point is that the labor charges, cost of pots, etc., will be considerably more with the crucible process than the labor charges and repairs with the electric furnace per ton of steel produced. The cost of electrical energy is only a small item in the total cost. Thus, in the Kjellin process (page 66 of the report) the cost of electrical energy for producing 1000 kgs. of ingots is \$1.48 and the total cost \$37.48. Thus increasing the cost of electrical energy by 100 per cent means to increase the cost of the product by less than 4 per cent. As Mr. Harbord puts it, the advantage in working costs with the electric furnace is so considerable that, under the same conditions as to labor, it should eventually supersede the crucible process, especially as there seems to be every reason to believe that the special alloy steels now being so largely introduced for high-speed cutting tools could be readily made in this furnace.

Concerning structural steel to compete with Bessemer and open-hearth steel, the conclusion of the report is that it could not be economically produced in the electric furnace. This conclusion agrees exactly with the status of the industry, since the electric furnace is nowhere employed to compete with Bessemer or open-hearth processes. However, most interesting is the reasoning of Mr. Harbord on which the conclusion of the report is based. Mr. Harbord says (page 74 of the report), "The Héroult furnace is extremely well designed, and I see no reason why furnaces up to 10 or possibly 15 tons should not give satisfactory results; but at present I should hesitate to recommend larger furnaces than these." For small size electric furnaces there is a balance in favor of electric smelting compared with gas-fired Siemens furnaces of the same size, assuming the cost of materials and labor to be the same. But on the basis of the statement quoted above Mr. Harbord naturally reaches the conclusion that furnaces of this small size could not hold their own against gas-fired furnaces of 40 to 50 tons' capacity, or against the still larger furnaces of 100 to 200 tons, working on the Talbot system, where labor charges are reduced to a minimum. It is also true that in manufacturing on a large scale, pig ore and scrap would have to be used with a resulting greater consumption of electrical energy, while the fuel consumption is reduced in the large gas-fired furnaces. Nevertheless, the result of the Commission in this special point is essentially based on the present impracticability of constructing large electric furnaces for this purpose, while it appears that this difficulty is not inherent in the electric furnace as such, but may be overcome by judicious design.

Concerning the reduction of pig iron from ore, the conclusion is reached that the electric furnace can compete with the blast furnace only when electrical energy is very cheap and fuel very dear; on the basis of electrical energy of \$10.00 per hp.-year, and coke at \$7.00 per ton, the cost of production in the electric furnace is approximately the same as the cost

of producing pig iron in a modern blast furnace. This is Mr. Harbord's conclusion, based on the experiments made at Livet. It was impossible to make tests under more favorable conditions, since there is nowhere a plant reducing iron ore in the electric furnace to pig iron on a commercial scale. It is only fair that Dr. Haanel calls attention to the fact that the figures obtained in these tests were obtained in experiments made off-hand, so to say, in furnaces not at all designed for the reduction of iron ore. These tests really permit nothing more than to form a general opinion as to the commercial possibilities of the process, and we believe that the result as it stands will surprise even the best friends of, and believers in, the future of the electric furnace. We do not mean to say that the results prove that electric reduction of iron ore would be practical and economical in Canada with improved furnace design; the fact is that the results of the Commission do not allow to draw any exact conclusion as to this point, but it must undoubtedly be admitted that better results can be obtained with better designed furnaces.

Since the report was issued in the first days of November, our weekly contemporaries have already had the privilege of discussing it in their columns. Among the prominent technical journals of this country, we noticed two which have expressed editorially opinions on the report and the general problem. The leading iron and steel paper, to which we have already referred, says: "Above all, the fact is now made plain that thus far the adventurers in this new field of metallurgical work have accomplished nothing which even faintly suggests the revolutionizing of existing methods in the iron and steel industry." A prominent civil engineering paper considers the results concerning pig iron as "the most important conclusion of the report," and passes over the crucible steel question with seventeen words. We heartily disagree with our contemporaries. The introduction of the electric furnace into the iron and steel industries is controlled by the same common-sense and common-place principles as any other industrial development. There may be people who think that there is glory in attacking a position on its very strongest point, instead of selecting the weakest spot, but surely this is not good business. The introduction of the electric furnace has gone on exactly in the way logically to be expected; the first application was to the ferro-alloy and crucible steel problems, there is later time to look out for other possibilities. Even if these other possibilities should not realize, the special steel field is wide enough, or we should rather say, it will undoubtedly become wide enough, just as the result of the electric furnace process. If Dr. Héroult can do what he claimed in his recent Congress paper—that at a cost of not more than 50 cents per ton, any steel delivered in molten state, such as tapped out of a Siemens furnace or obtained from a Bessemer converter, can be converted into steel of any desired composition, containing not more than 0.01 sulphur and 0.01 phosphorus—he is justified in predicting a revolution in the uses of high-grade steels. If they can be had cheaply, they will undoubtedly be used much more extensively. The electric furnace will then work as an adjunct to the blast furnace, the Bessemer converter and the open-hearth furnace. The cost

of electrical energy should not trouble our "conservative" contemporaries in this special case since the utilization of waste gases for driving gas engines, coupled to generators, is a combination which has already proven successful.

The make-up of the Canadian Commission was singular in one respect. It consisted of a mining expert, a metallurgist and an electrician who made the measurements, but no electric furnace specialist, as might, perhaps, have been expected in an electric furnace Commission. Probably the latter was omitted to prevent any criticism to the effect that the Commission was influenced by an "interested party." As it was made up, its report has been received on all sides as impartial. This make-up is also presumably the reason why the report is chiefly descriptive, and contains only occasionally notes as to improvements of furnace design. Instances are the low power factor of the Keller furnace, due to the iron casing, and the omission of the water-jackets around the electrodes in the Héroult furnace when visited by the Commission. The latter defect has been remedied in the meanwhile with remarkable results. There are undoubtedly other points in which the designs of some of the furnaces described could be improved. Here is a promising field for electric furnace designers.

ALUMINIUM.

A discovery which may, in the next decade, influence to some extent the course of the aluminium industry, is the recognition that certain so-called clays, known for years in India as "laterites," are in reality more or less pure bauxites, some of them, the high-level deposits, being as pure as the best Arkansas or Georgia bauxites. Miss Buena Pool gave interesting details concerning this discovery, in a paper recently read before the Faraday Society at London and abstracted elsewhere in this issue. With the cheap labor of India, these materials can be mined and prepared at a very low cost. With the abundant water powers which the edges of the Deccan table-land furnish, there is no lack of power for the electrical purification and reduction of these ores. Considering the extent to which the metal workers of India, particularly of Madras, are importing sheet aluminium blanks and working them up into cooking utensils and military equipments, there is no doubt of the large market directly at hand for the aluminium produced. Further, we believe that none of the present methods of preparing or producing aluminium have been patented in India, so that the development of the industry there appears to have before it a perfectly clear field, with a ready-prepared market for its product. Our English cousins, with a lien on India, so to speak, will be remiss if they overlook this combination of opportunities. Before dropping this subject, we will risk criticism by pointing the moral to adorn the tale. The moral is, do not take too much for granted. Because some geologist, very probably without making any test, called the laterites, in an offhand manner, clays, everyone else took it for granted that they were, until the open-minded discoverer, anxious to verify truth for himself, made an analysis and found they were something entirely different. Our compends of information are full of such misstatements, and discoveries are literally "under our noses" if we search honestly and without prepossessions.

LABORATORY COURSE IN INDUSTRIAL CHEMISTRY.

A paper on this subject by Prof. WILLIAM H. WALKER, of the Institute of Technology, of Boston, and originally published in the *Technology Review*, vol. VI., brings out forcibly some well-taken points with respect to university education of the future chemical engineer. Aside from familiarizing the student with some of those pieces of general apparatus which adapt themselves to reproduction and operation on a laboratory scale, there is not a great deal in a lecture course on industrial chemistry that can be efficiently emphasized by work in a laboratory. By his work in a laboratory devoted to industrial chemistry the student should gain a new point of view, or what might be termed the economics of chemistry, is to be studied.

Throughout the other work in his course, the student gives no thought to the relative cost of the material he uses. It is of no moment to him in analytical chemistry, for example, whether the reagent be cheap or expensive. If the analysis is to be completed, the reagent must be used. Likewise, if a precipitate is to be washed or a substance dissolved, water must be used, irrespective of its volume. If the resultant washings or solution be too dilute or of too great a bulk, the water must be driven off, regardless of the cost of evaporation. In industrial chemistry, however, a reagent may be used only when its cost does not raise the total expense of the process above a fixed maximum. A sludge or residue may be washed only to the point where the value of the material held in solution does not fall below the cost of driving off the water.

A valuable introductory experiment is the purification of common salt, the analysis of which is given, to be used in the electrolytic preparation of caustic soda and chlorine. This is interesting for several reasons. First, because salt sufficiently pure for commercial electrolysis is itself a very cheap material, and the cost of reagents used in purifying a crude salt may easily exceed this value; second, the mechanical difficulties of the process are small; third, the reactions involved are simple and easily controlled, and fourth, a good result may be demanded and obtained. Although the necessities of the case have been carefully explained, the student will almost invariably propose throwing out the iron and aluminium by means of ammonium hydrate, separating the calcium as oxalate, and the magnesium as phosphate. He is here using the knowledge gained in his study of qualitative analysis, and this is eminently desirable; but, although he knows a thing to be possible, he must also ask himself: is it practicable? It does not here occur to him that not only are these reagents very expensive, but that he is contaminating his salt with ammonium chloride.

It is usually a revelation to him to find that anything so "scientific" as a solubility table is of value in determining the volume of water necessary to handle a given weight of salt, that anything so unscientific as a Beaumé hydrometer is an instrument with which he must ultimately become familiar, that boiling off water is expensive, etc.

Whether such an experiment is considered successful or not depends not only on the purity of the product or the percentage yield, but upon the cost of the finished product as determined by the cost of the original salt and the materials used in its purification. The statement of the results of the operation should show the weight of salt taken, the amount added in the form of reagents, the amount returned to the system as mother liquor, that sent back to the water supply in the form of wash water from the various precipitates, and the weight of pure salt recovered either in the form of brine, as determined by its density, or recovered as pure crystal salt. Great care should be taken to impress upon the student that the value thus obtained does not represent the manufacturing cost of the purified salt; that the very important factors of labor,

interest on investment and depreciation of plant have not been included.

The influence of the mechanical difficulties inherent in carrying on a given process as contrasted with the cost of raw materials is well shown in the preparation of barium nitrate by two different methods.

The laboratory has, of course, its limitations, and in determining the depreciation of the apparatus used in a given operation, this limit is very soon reached. Such matters as labor, cost of plant, interest on investment, insurance, etc., do not lend themselves at all to laboratory treatment. On the basis of the experiments, however, they can be discussed in conference with greater profit and to a much better advantage than if the laboratory work had not previously been done.

In addition to acquiring a general idea of what the factors are which enter into an industrial problem, the student may at the same time have awakened in him an interest in what has been termed the "spirit of research." The conditions influencing or controlling the result may be systematically varied in such a way that each man or group of men will, in performing the experiment, contribute data toward its solution. A good example of this idea may be found in the electrolysis of brine for the production of bleaching liquor.

Dr. Walker emphasizes the importance of the preparation of a written report upon some problem, the solution of which has been attempted in the laboratory—such a report as the chemist of a works would be expected to make to its superintendent. The student should also thoroughly understand the value of a well-known note-book, not only as a record of experimental data obtained, but as legal evidence in case the matter contained therein becomes the subject of litigation.

As a further advantage possessed by a course in industrial chemistry, though in no way limited to it, may be mentioned a certain mental stimulus which it furnishes to original, independent thinking. Even though the subject of mental discussion be the same, if the point of view be changed, the mind is refreshed. If, for example, after studying the speed of migration of the ions and their transference numbers as a problem in theoretical chemistry, the same subject be taken up in an attempt to increase the concentration of caustic soda in the effluent from an electrolytic cell, the student can work with greater mental vigor than if he continued to think upon the theoretical problem alone.

Dr. Walker concludes that such a course, as outlined above, will never take the place of an apprenticeship in a factory or works—will not make a finished engineer, but it will contribute toward giving that method of thought and work which produces the man "who knows what to do when there is something to be done."

LOCAL SECTIONS OF THE AMERICAN ELECTRO-CHEMICAL SOCIETY.

The Philadelphia and Madison local sections of the American Electrochemical Society have started the work of the season.

On a preliminary meeting of the Philadelphia section we reported last month. In the meanwhile, the first meeting has been held in an informal and very satisfactory manner, the subject of the discussion being electric furnace methods in iron and steel industries. Mr. S. S. Sadtler and Dr. Geo. P. Scholl reported on special points on new developments in this line, and an informal and animated discussion followed.

The local section at Madison, Wis., held its first meeting on Nov. 21 and re-elected as officers for the coming year: Prof. C. F. Burgess, chairman; Mr. F. L. Shinn, secretary and treasurer. Dr. Kahlenberg addressed the meeting upon electrochemical features at the recent International Congresses at St. Louis. It was decided to hold meetings each month during the college year.

ELECTRIC FURNACE PROCESSES FOR IRON AND STEEL MANUFACTURE.

The full report of the Commission, appointed by the Canadian Government to investigate the different electrothermic processes for the smelting of iron ore and the making of steel in operation in Europe, has just been issued. Since we have repeatedly referred in our columns to the work of this Commission, we will give here only a summary of the report, with special references to those points which are new in it.

The report covers 223 pages and is typographically very handsome, well printed and profusely and nicely illustrated. Besides the full account of the tests made by the Commission and the results obtained, the report contains, in the description of processes, much information which was heretofore available in scattered form only. For this reason alone, it is very valuable, and will remain for some time to come the handiest source of information for those interested in the subject.

The first part of the report gives descriptions by the chairman of the Commission, Dr. EUGENE HAANEL, of the Kjellin, Héroult, Stassano and Keller processes, and short notes on the Harmet and Gin processes. All essential points brought out in this description have already been noticed in our columns. The descriptions in the report are given in a concise and clear way, with valuable detailed drawings of the furnaces employed.

This part of the report is concluded by the conclusions reached by Mr. W. F. Harbord as the metallurgist of the Commission, to which Dr. Haanel adds some notes. These will be given below in connection with Mr. Harbord's report.

REPORT OF ELECTRICIAN.

The second part of the volume is the report of the electrician, Mr. C. E. BROWN, who gives a full account of the measurements of the electrical energy made in the various furnace plants visited. A summary of his results is given as follows. For the horse-power-year, in all cases, a year of 365 days of twenty-four hours is assumed, and where the power is employed a smaller number of days, the cost must be corrected accordingly. The costs are based on a rate of \$10 per electric horse-power-year.

SUMMARY OF RESULTS OBTAINED FOR STEEL.

	Kjellin Process.		Heroult's Process.				Keller Process.
	Charge No. 546.	Charge No. 547.	Charge No. 655.	Charge No. 660, Tool Steel.	Charge No. 660, Structural.		
Total kilowatt hours.....	857	994	1,410	2,580	1,680	1,325	
Total horse-power, years.....	1.183	0.154	0.219	0.40	0.361	0.206	
Output of ingot in kilograms.....	1,090	955	1,283	2,341	2,341	1,650	
Kilowatt hours per ton of ingot.....	882	1,040	1,100	1,100	718	804	
Horse-power-years per ton of ingot.....	0.13	0.16	0.17	0.17	0.111	0.125	
Cost of electric energy per ton of ingot at \$10 per h. p. year.....	\$1.90	\$1.00	\$1.70	\$1.70	\$1.11	\$1.25	

SUMMARY OF RESULTS OBTAINED FOR PIG IRON.

	Heroult Process.	Keller Process.	
		First Run.	Second Run.
Total kilowatt hours.....	3,980	33,700	10,840
Total horse power, years.....	0.51	5.23	1.09
Total output of pig iron in kgs.....	999	9,868	6,602
Kilowatt hours per metric ton of pig.....	3,880	3,420	1,630
Horse-power-years per metric ton of pig.....	0.525	0.53	0.25
Cost of electric energy per metric ton of pig at \$10 per h. p. year.....	\$5.25	\$5.30	\$2.50

With respect to the above figures, the following remarks may be made. For the test of the Héroult process for pig iron a voltmeter and ammeter were used. "No determination of the power factor could be obtained, but a value of 0.75 would appear to be reasonable, and is assumed for purpose of calculation."

The first run of the Keller process for making pig iron was made with furnaces Nos. 11 and 12; the energy was measured by a recording wattmeter and the power factor determined by means of an oscillograph. The second run was made with furnaces 1 and 2 and electrical readings were taken on the switch board voltmeter and ammeter, which were afterwards calibrated, and the power factor at the electrode was determined by means of the oscillograph. It will be observed that the consumption of electrical energy per ton of output, is less than one-half as great in the case of furnaces Nos. 1 and 2 (second run) as in furnaces Nos. 11 and 12 (first run). "This great variation is not to be ascribed to any material difference in design or construction, but rather to the conditions of operation. The power factor for furnaces Nos. 11 and 12 is fairly low, and for Nos. 1 and 2 extremely low. This is doubtless due mainly to the iron casing which forms a magnetic circuit around each shaft of the furnace, and is highly magnetized by the large current giving to the circuit a very high reactance. In case of the erection of a new plant, this iron casing would be omitted between the two shafts, or entirely. Either change should result in a very great improvement of the power factor, and a corresponding diminution of the kilo-volt-ampere input required, and give very much better conditions of operation for the alternator. A further improvement of the power factor would be effected by using current at 25 cycles. There seems to be no inherent reason why a reasonably high power factor cannot be obtained by careful attention to all of the details of design affecting the electric circuit."

Charge No. 546 of the Kjellin steel process was for making one per cent carbon steel, charge for 547 for making 0.4 per cent carbon steel. (See the metallurgist's report below.) Concerning the Kjellin furnace, Mr. Brown makes the following remarks: "The principal disadvantage, electrically, in this system is the very low power factor obtained, resulting from two causes, namely, the very high self-induction of the secondary due to its wide separation from the primary by the furnace wall and ventilating space, and its low resistance. In the present case, with a periodicity of 13 to 14 cycles, the power factor is only slightly above 0.6 at full load, and with increased capacity the resistance will be reduced, while the inductance remains about constant, giving a still lower power factor, or requiring a lower frequency."

"Mr. Kjellin has calculated that for a furnace of 15 tons capacity per charge, it would be necessary to reduce the periodicity to about 4 cycles per second to get a power factor of 0.6, or that for three such furnaces, surrounding the three legs of a three-phase transformer, and made common in the center, with a joint capacity of 45 tons, the same frequency would be required. This extremely low periodicity, combined with a low power factor, will make the cost of generators much higher than for standard machines."

"The system has, on the other hand, two important advantages. First, that it takes current directly at a voltage suitable for generation and transmission over distances, the 3000 volts here used being capable of increase to 5000 or 6000 volts, where required, which should be ample for any case arising in this class of work; and, second, that no cables, connections, or electrodes, with their attendant cost, loss of power and necessity of attention, are required in the secondary circuit, and for large furnaces, using currents from 10,000 to 30,000 amperes, this is an important item."

REPORT OF METALLURGIST.

The third part of the volume comprises the report of Mr. F. W. Harbord, the metallurgical expert of the commission. Since it contains much exact information on the composition of the products of the various furnace processes, we will abstract it at greater length.

KJELLIN PROCESS.

The raw materials used in Gysinge are best Swedish pig iron (Dannemora) and bar scrap Walloon iron of the fol-

lowing composition. The pig iron contained 4.400 per cent C, 0.080 Si, 0.015 S, 0.018 P, 1.000 Mn, 0.015 Cu, 0.035 As. The Walloon bar iron contained 0.200 per cent C, 0.030 Si, 0.003 S, 0.009 P, 0.120 Mn, 0.008 Cu, 0.035 As.

The furnace is never completely emptied. Approximately 700 kg. are always left in it, the furnace men having instructions always, as far as possible, to leave the same quantity in the furnace.

The first experimental charge (No. 546) was arranged so as to produce a high carbon steel containing about 1.0 per cent of carbon. For this purpose the charge was made up as follows:

	Kilograms.
Pig iron (white)	300
Steel scrap	125
Bar scrap	600
Metal in furnace, estimated.....	700
Silicon pig, 12 per cent.....	30
Ferro-manganese, 80 per cent	1
Total charge	1,756

The steel scrap was from previous charges and contained about 1.0 per cent of carbon. Only a part of the materials was charged at the commencement, but as the charge melted, further additions of pig iron and scrap were made. The bar scrap iron was more or less rusty, and consequently had some oxidizing action upon the impurities in the pig iron; as the furnace is never completely emptied, the slag from previous charges gradually accumulates, and is removed in small quantities, from time to time, from the top of the bath of metal. About 7 kgs. of slag, somewhat ferruginous, were removed during the working of this charge. Assuming that no oxidation had taken place during melting, the steel should have contained about 1.40 per cent of carbon, but owing to slight oxidation, the actual percentage was 1.082.

When the entire charge was melted, the current was continued until the temperature of the bath had acquired the necessary temperature for tapping, and the steel was then tapped into a ladle in the usual way and cast into ingot molds. The time taken for the working of the charge was six hours. The metal ran from the ladle quite freely, and no skull was left behind. It was very quiet in the ingot molds, and the weight of ingots was 1030 kgs., or 2271 pounds.

Drillings were taken from three 5-inch ingots and one 7½-inch ingot at top, center and bottom, and reserved for analysis. The analysis of an average sample is 1.082 C, 0.194 Si, 0.008 S, 0.010 P, 0.240 Mn, 0.012 As, 0.031 Cu, trace Al.

Analyses of drillings from top, bottom and center of various ingots will be seen from the following to be almost identical:

	Drillings from Top Bottom and Centre of 7½ in. Ingot.			Drillings from three Separate Ingots, Nos. 1, 2 and 3.		
	Top.	Centre.	Bottom.	No. 1, Top.	No. 2, Centre.	No. 3, Bottom.
C	1.083	1.077	1.050	1.086	1.086	1.070
Si	0.194	0.205	0.196	0.206	0.204	0.205
S	0.008	0.010	....	0.009	0.010	....
P	0.009	0.011	0.011	0.010	0.011	0.009
Mn ..	0.242	0.260	0.250	0.250	0.246	0.250

The energy consumed was given above in the report of the electrician.

The second experimental charge (No. 547) was arranged so as to make a medium carbon steel of about 0.5 per cent carbon. Besides the 700 kgs. of steel remaining in the furnace, the charge was made up as follows:

	Kilograms.
Pig iron	100
Bar scrap	825

Steel scrap	100
Ferro-manganese, 80 per cent	1
Silicon pig, 12 per cent silicon	35
Total new charge.....	1,061

Eight hundred and seventy-six kilograms of ingots and 79 kgs. of scrap were produced. The analysis of an average sample being 0.417 C, 0.145 Si, 0.008 S, 0.010 P, 0.110 Mn, 0.020 As, 0.032 Cu, trace Al.

It was then decided to make a cast of low carbon (0.20 per cent or less) steel. But there were difficulties in getting a good tapping heat, on account of the limited amount of power available at the works. Owing to the deficiencies in power, it was most difficult to obtain the necessary temperature for tapping, in a reasonable time, with the result that the metal was kept in the furnace for from 1½ to 3 hours longer than it should have been, exposed to the action of the oxidizing slag. Another difficulty was that the furnace, having been designed especially for the manufacture of high carbon steels suitable for tool purposes, no slag hole for the withdrawal of the slag had been arranged for, as it had been found that in making these high carbon steels the small amount of slag produced could easily be removed through the charging doors. In making the soft steel, however, far larger quantities of slag are produced, and it was not found possible to remove the slag from the top, with the result that considerable difficulty was experienced in producing dead melted metal. Given a furnace slightly altered, so that the slag could be removed from time to time, and ample electric power to produce the necessary temperature rapidly, there is not the slightest doubt that dead soft steel could be satisfactorily produced.

As regards the mechanical and working properties of the steel produced, whether high or low carbon, there can be no question that the steel is of the highest quality. Experiments were also made at the Royal Arsenal, Woolwich, to test the capabilities of the steel when used for turning. The tools were all forged the same shape, particular care being taken that the tool angles were the same in each case. For comparison tests were made with similar tools forged from the best crucible steel used at Woolwich, known as grade "A," and also with tools forged from Mushet's steel. The steel operated upon was untempered gun steel, containing 0.3 per cent of carbon. As compared with grade "A," the results show that, speaking generally, there is little difference between this and most of the steels experimented with. On the other hand, the material was not so good as the Mushet steel. "It is only claimed for the above steel that they are equal to the carbon crucible steels, and the comparison with Mushet's steel was made to see if they were in any way superior to the carbon steels. The special properties of high-speed tool steels are due to the steel being alloyed with special metals, and to a particular heat treatment, and from a metallurgical point of view there should be no difficulty in making these special steels in the electric furnace."

The cost of production necessarily varies with local conditions, such as the cost of labor, refractories, electrical energy, and pig iron and scrap. Each of these heads is therefore considered separately.

Labor.—There were five men and one boy employed on the furnace at Gysinge for each twelve-hour shift, the output being on an average 3000 kgs. per twenty-four hours. Mr. Harbord, however, remarks that there seems no reason why the size of the furnace should not be very considerably increased, and with furnaces of five to ten tons capacity the labor cost would be very greatly reduced. "Five men and one boy could do all the necessary work if they had a little assistance in charging on a five-ton or even a ten-ton furnace, without being in any way overworked."

Pig Iron and Scrap.—Since the actual cost of these materials will vary within very wide limits, it will suffice here to give

what is a typical or average charge to produce one ton of ingots:

	Pounds.
Best pig iron	600
Best Walloon bar scrap	1,200
Best tool steel scrap	188
Silicon pig iron, 12 per cent silicon.....	60
Ferro-manganese, 80 per cent	2

Total weight to produce 1 ton..... 2,050

Refractory Materials and Repairs.—From Mr. Kjellin's works books, extending over a period of ten weeks, during which 309 tons of ingots were made, it is shown that the cost of cutting out old lining, relining furnace, all refractories (magnesite) and labor charges came to 60 cents per 1000 kgs., equivalent to 54 cents per ton of 2000 pounds of ingots produced.

Electrical Energy.—According to Mr. Kjellin's books, the energy consumed in producing 309 tons of ingots during ten weeks or seventy working days, was 41.3 e. hp.-years, costing \$1.34 per ton at a cost of \$10.00 per e. hp.-year. This agrees well with the figures given above in the report of Mr. Brown.

So far no special alloys for the manufacture of high-speed cutting tools have been made at Gysinge, but there appears to be no reason why this should not be done. The furnace is simply a large pot furnace, and has the additional advantage that there is not the slightest danger of the steel taking up sulphur during the process of melting, and by making suitable changes, steel of any required composition can be made.

In Mr. Harbord's opinion, the furnace would require considerable modifications before it could be conveniently used for the manufacture of mild steel to compete with the Siemens furnace, as the difficulty of removing the whole of the slag, while retaining a small portion of the metal in the furnace, would, he fears, be considerable, and he anticipates that repairs could not be so readily effected if the walls were badly cut by the slag, as in the case of an ordinary Siemens furnace. "Mr. Kjellin has, however, shown so much ingenuity in surmounting the difficulties in connection with the manufacture of high carbon steel, that, given the opportunity to experiment with a furnace on a reasonable scale, it is quite possible that he may be able to overcome these difficulties and make the manufacture of mild steel a commercial success. The process, as at present worked, is admirably adapted for the highest class of steel from pure materials, and the only objection to it is that it is limited to these pure materials, and can only be used where they are obtainable." Mr. Harbord does not think in its present stage of development it is adapted to treat ordinary pig iron and miscellaneous scrap of more or less irregular composition as the complete elimination of any impurities present could not always be relied upon. Under the special conditions existing at Gysinge and in some other places, it is capable of doing most excellent work, and is a most efficient and economical metallurgical appliance.

HEROULT PROCESS.

Concerning the results of tests of the Héroult process, made at La Praz, the following information is given.

The usual charge was about three tons, and consisted entirely of miscellaneous scrap, with suitable additions of ore and lime. As in the case at Gysinge, it was arranged to make steel of varying carbon content, and the first charge was a low-carbon steel for transformers. As only a small quantity of steel was required, an exceptionally small charge was made. The charge (No. 658) was as follows:

	Pounds.
Miscellaneous scrap	3,307
Iron ore	330
Lime	246

The scrap was charged with some lime and then additions of ore and lime were made from time to time.

When the bath of metal and slag was completely melted, the slag was poured off, great care being taken to remove the slag entirely; a new slag was then made by adding about 55 pounds of lime, 15.5 of sand, and 15.5 pounds of fluorspar. This was melted and kept in the furnace for some time, when it was poured off as completely as possible, the last traces being raked off the surface through the pouring door. Another addition of lime and fluorspar, etc., in the same proportion as the last, was then made to form a finishing slag to remove the last traces of impurity; about 1.5 pounds of ferro-manganese was added, and the charge was poured into the ladle, a little aluminium being thrown into the ladle before the metal was teemed into the ingot molds.

The furnace was ready charged at 7:45 p. m., and the current put on, and it was poured at 12:15; time, 4½ hours. The very short time taken for the operation was due to the smallness of the charge, and to the fact that no time was required for recarburizing the very low carbon steel. The steel, when teemed, ran from the ladle freely, no appreciable scrap being left behind; it was very quiet in the ingot molds, and the steel ingots were exceptionally sound for steel of this quality. The yield was:

	Pounds.
Ingot	2,820
Scrap	9

This is equivalent to 2338 pounds of scrap for every 2000 pounds of steel produced. The analysis of the scrap and steel was as follows: Scrap charged—0.110 C, 0.152 Si, 0.055 S, 0.220 P, 0.130 Mn, 0.089 As. Steel produced—0.079 C, 0.034 Si, 0.022 S, 0.009 P, 0.230 Mn, 0.096 As, trace Cu.

This was a special steel for transformers, and in it the welding qualities were purposely sacrificed in order to obtain the special qualities required by the electrical manufacturers. In other respects the steel gave excellent results; it forged remarkably well, without a trace of red shortness, and gave very good cold, bending tests. The electrical energy is consumed at the rate of 0.153 hp.-year per ton of steel produced.

The next charge (No. 660) was arranged to produce a high carbon steel. The same scrap was used, and the charge was as follows:

	Pounds.
Miscellaneous steel scrap	5,733
Ferro-silicon	19
Iron ore	430
Lime	346
Ferro-manganese	3.3

Commenced to charge at 11:40 a. m., current put on at 11:50, but all the current not on till 12:45; tapped at 7.4 p. m.; time, 8 hours.

The scrap and part of the lime were charged before the current was switched on, and the remainder of the ore and lime was added during the melting. After the charge was completely melted, the slag was poured off, great care being taken to remove it as in the previous charge, and a second slag was made by adding 88 pounds of lime and twenty-two pounds of sand, and twenty-two pounds of fluorspar. This was melted and removed, and a finishing slag formed by the addition of similar quantities of lime, sand and fluorspar. The charge was completely melted at 5 p. m., five hours and twenty minutes after charging, and if soft steel had been required, the furnace would have been ready to tap at this time.

The bath, however, had to be recarburized to the required point, and this was done by adding in the furnace "carburite," a mixture of pure iron and carbon, until the required degree of carburization was obtained, 19 pounds of 12 per cent ferro-silicon being also added at the same time. The charge was sampled in the usual way with a spoon ladle, and when the furnaceman was satisfied that the bath contained the required percentage of carbon, the metal was poured into the ladle, a little aluminium added, and the steel teemed into the ingot molds. The metal ran very freely, leaving no skull in the

ladle, was quiet in the molds, and forged extremely well in the press; the welding tests were very satisfactory. The yield was 5161 pounds, equivalent to 2000 pounds of steel ingots for every 2230 pounds of scrap and metal charged. The following is an analysis of the steel: 1.016 C, 0.103 Si, 0.020 S, 0.009 P, 0.150 Mn, 0.060 As, trace Cu, trace Al.

The electric energy used during the working of the charge was 2580 kilowatt-hours, equivalent to 0.395 electric hp.-years, equal to 0.153 electric hp.-years per 2000 pounds of steel produced.

Had this charge been required for soft steel, it would have been ready to tap at 5 o'clock, when the consumption of electric energy was 1680 kilowatt-hours, equivalent to 0.257 e. hp.-years, equal to 0.100 e. hp.-years per 2000 pounds of steel.

It will be noted here that, starting entirely with nearly carbonless scrap iron, the first product obtained is soft steel; to produce high carbon steel this has to be carburized by suitable additions. Consequently, the metal has to be kept longer in the furnace to produce high carbon steel than low carbon steel, and the consumption of electric energy is greater in the former than in the latter case. This is just the reverse of the method of working at Gysinge, where the time taken in producing soft steel is longer than for high carbon steel. The methods of working, however, in each case depend more upon the materials available than any other consideration, and there would be no difficulty in making high carbon steel without recarburizing, by melting down a suitable mixture of pig iron and scrap in the La Praz furnace; and, on the other hand, pure scrap could be melted down in the Gysinge furnace and recarburized at the end of the operation, if desired.

Concerning the cost of production in the Héroult process, the following data are given. The consumption in electrodes, when working continuously, was 500 kgs. per week, and 50 per cent of old material, costing two centimes per kg., was mixed with 50 per cent of new material, costing 10 centimes per kg., thus costing about 30.00 francs for an output of 30 tons of steel.

The average output per twenty-four hours was 4 tons; figures furnished by Mr. Héroult from his book showed an output of 120 tons for 30 days consecutive work, and he considers that he can make 150 tons in this time. The average time for each charge was nine hours, and there were 5 men employed on the furnace each shift, including the foreman. In these men are included the ladleman and pitmen. The repairs and renewals are somewhat heavy; burnt dolomite costing 3 francs per ton of steel produced, magnesite 1.5 francs and acid refractories, including roof, about 2.5 francs per ton, making a total of \$1.40 per ton for refractory materials.

[In a statement printed in Dr. Haanel's report, Dr. Héroult says that since the Commission visited LaPraz the steel furnace has been materially improved by the addition of water-jackets round the electrodes. "The effect is this: The output of the crucible has passed from 4 tons to 7 tons in twenty-four hours. The absence of air is so complete that we obtain a certain percentage of carbide of calcium in the slag. The loss of raw material has also greatly diminished."]

Since any scrap is suitable for the process, the price of the raw material is never likely to be very high, and may, as a rule, be taken to be about the same price as pig iron delivered at the same place.

The cost, as regards materials and labor, will be practically the same as for a gas-fired Siemens furnace of the same size, making similar steel. Any difference in the cost will be due to the cost of electric energy and electrodes, as compared with the cost of fuel. Repairs will probably be higher, but not sufficiently to affect the cost of production. In a small Siemens furnace of this capacity, the fuel consumed would vary from 1000 pounds to 1800 pounds of good slack coal, i. e., small coal, per ton of steel produced. Such coal would probably cost \$5.00 to \$5.50 per 2000 pounds in Canada, and

assuming 1200 pounds to be used per ton, this would be \$3.00 per ton of steel. The cost of electric energy, at \$10.00 per e. hp.-year, would be \$1.53, and electrodes are estimated to cost 20 cents, making a total of \$1.73 against \$3.00, so that there is a balance in favor of electric smelting, assuming the cost of materials and labor to be the same.

If the Héroult process is compared with the crucible process, the advantage in working costs with the electric furnace is so considerable that under the same conditions as to labor, it should eventually supersede the crucible process, especially as there seems every reason to believe that the special alloy steels now being so largely introduced for high-speed cutting tools could be readily made in this furnace.

How far this electric furnace can compete with the ordinary Siemens process under the conditions prevailing in Canada is a much more difficult question to decide, as the cost of production largely depends upon the output, and to get a large output with low labor charges means very large furnaces, as practically a 30 or 40 ton furnace requires hardly any more men than a 3 or 4 ton furnace, provided mechanical appliances are arranged for charging. Mr. Harbord thinks that the Héroult furnace is extremely well designed, and he sees no reason why furnaces up to 10 or possibly 15 tons should not give satisfactory results, but at present he hesitates to recommend larger furnaces than this. He does not think, therefore, that furnaces of this size could hold their own against gas-fired furnaces of 40 to 50 tons capacity, or against the still larger furnaces of 100 to 200 tons, working on the Talbot system, where labor charges are reduced to a minimum. Moreover, in making structural steel in large quantities, it would not be possible to get sufficient quantities of scrap so that pig, ore and scrap would have to be used, and this would take a longer time to convert into steel than scrap charges, and the consumption of electrical energy would be greater. On the other hand, in the large gas-fired furnaces, the consumption of fuel per ton of steel is reduced.

Brief notice is made of the Keller steel furnace which in principle is identical with the Héroult furnace and varies only in details of construction.

Mr. Harbord concludes that the Kjellin, Héroult, and Keller processes of electric steel manufacture "are all capable of producing equally good steel and the selection of one or the other would depend upon local conditions.

"The Kjellin process is undoubtedly the nearest approach to the crucible process, and given a high-class pig iron and scrap has much to recommend it, a special point being that the operation is conducted in a closed crucible or hearth, and there is no possibility of impurity being introduced by contact with electrodes. Its application, however, is limited, and, although some purification can be effected during the melting, the quality of the steel will largely depend upon the raw material being very pure, in the same way, although to a somewhat smaller extent, than in the crucible process. To what extent the phosphorus, etc., can be removed in this process our experiments do not enable us to say, as all the charges we followed were made from purest materials, but the furnace is more suitable for replacing the crucible steel melting than for dealing with miscellaneous scrap and pig iron similar to that used in a basic or acid Siemens furnace.

"On the other hand, furnaces of the resistance type, with electrodes, can treat phosphoric scrap and pig iron in the same way as a gas-fired Siemens furnace. The neutral atmosphere and the intense heat which it is possible to obtain enable very basic slags to be used, and the mechanical arrangements allow the ready removal of the slag so that a pure non-oxidizing slag to remove the last traces of phosphorus can be ensured at the end of the operation. This undoubtedly opens a larger field for the resistance furnace, as in many districts common scrap can be obtained at a moderate price, where materials suitable for the induction furnace could only be obtained at a prohibitive price. They are,

as regards quality, both able to make highest class carbon steels, but from a practical point of view, the resistance furnace is more adaptable as regards its raw material, and has the advantage of being very similar in general design to an ordinary Siemens furnace, so that so far as the metallurgical operations are concerned, repairs, etc., an ordinary steel smelter could in a very short time manage the furnace as easily as a gas-fired Siemens furnace.

"In the present stage of development, neither type of furnace can be regarded as a competitor to either the Siemens or the Bessemer processes for the production of rail and structural steel, and can only compete successfully in the production of high-class crucible steel or steels for ordnance and other special purposes made in the Siemens furnace. In cases where very large steel castings are required of crucible steel quality, several electric furnaces, working so that they could be tapped into a common receptacle, before pouring the steel into the mold, should give excellent results and be much more economical than the crucible process. Under favorable conditions, electric energy might compete with gas as regards cost, but until it is possible to use furnaces of from 30 to 40 tons capacity, the extra labor charges inseparable from small furnaces will prevent them from holding their own against the Siemens or Bessemer process."

The tensile tests of both the Kjellin and Héroult steels are all very satisfactory and are what one would expect from high-class steel containing different percentages of carbon; the maximum stress increases with the carbon to about 0.9 per cent, with a corresponding decrease in elongation and reduction of area. The steels were all heated to a temperature of 600° C., which is below the carbon change point, to remove any stress due to cold working. In the lower carbon steels the elastic limit is exceptionally high, the ratio of elastic limit to maximum stress being 70 per cent in No. 5 A, 82 per cent in No. 7 (658), and 70 per cent in No. 9 (559).

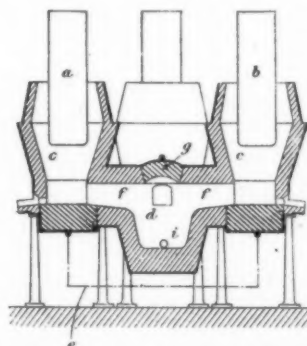


FIG. 2.—FOUR-HEARTH FURNACE.

Photomicrographs of the steels from the special experimental charges show that the structures were quite normal, except that in the low carbon steels the ferrite areas were exceptionally soft. They presented no special features, and, in fact, could not be distinguished from crucible steels.

REDUCTION OF PIG IRON FROM ORES.

A short test was made at La Praz in a Héroult furnace, commonly used for the manufacture of ferro-chrome and similar alloys. "This impromptu experiment has no bearing on the economic production of pig iron, and was simply arranged by Mr. Héroult to demonstrate to the commission how, even under most disadvantageous conditions, iron ore could be reduced with the electric furnace."

At Livet, the Commission saw direct smelting carried on continuously for some days, on a scale and under conditions which permitted one to form a general opinion as to the commercial possibilities of the process. These are the works of Messrs. Keller, Leleux and Co., and the furnace is designed by Mr. Keller. The furnaces are used sometimes for the direct reduction of iron ore, and sometimes for the production of ferro-silicon or ferro-chrome, according to the requirements of the firm at the particular time.

From the diagrammatic sketches (Figs. 1 to 3) in sectional plan and elevations, it will be seen that two or more ordinary furnaces with vertical electrodes are connected by a central well, and the current flows to and from each furnace through the vertical electrodes *a* and *b*. Preferably four hearths are connected, arranged so that the metal, as it is reduced, flows into the central well, from which it can be tapped into pig beds or a ladle to suit the particular requirements. "If four hearths (*cccc*) are used, they can be divided into two groups which are connected with each other in series, the two hearths forming each group being connected with each other in parallel. In such an arrangement the electric current will be broken during casting, when the well is emptied of its contents, and this would not only interfere with the working of the furnaces, but also with the working of the electric generators. To avoid this, the soles of the furnaces are made electrically conductive, and are connected with bars of copper (*e*), which connect hearths of opposite polarity in the manner shown in Fig. 1 to 3. As the flow of the current through the fused material decreases during casting, it flows through the soles of the hearths and conductors (*e*), and increases in direct ratio with the fall of the current in the fused mass connecting the hearths; and, finally, when the hearth is emptied, the entire current flows through the conductors (*e*).

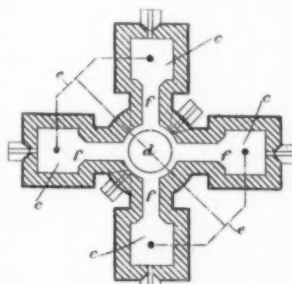


FIG. 3.—PLAN OF FOUR-HEARTH FURNACE.

"After casting the fused metal again collects in the crucible (*d*), and remakes the broken circuit, so that the current again begins to flow through the fused mass. These short-circuits prevent any irregularity or great variation in the distribution of the current, and for this arrangement at least two furnaces are necessary. In the event of the metal becoming chilled in the central well, it can be heated by a subsidiary electrode (*h*) to the required temperature for casting."

The furnace in which the first experiment was conducted at Livet consisted of two hearths connected by a well. The waste gases were allowed to escape and burn at the top of the furnace, and no doubt a distinct economy would be effected if the furnaces were made deeper than those at Livet, so that a longer column of descending materials would be able to absorb more effectually the sensible heat of the gases. There was one experiment made in these furnaces, lasting fifty-five consecutive hours, and a second lasting forty-eight hours, in two furnaces similarly designed, but without the well.

The points to which special attention was given during the investigation were: First, the output of pig iron for given consumption of electric energy. Second, the yield of metal per ton of ore charged. Third, the quantity of coke required as a reducing agent. Fourth, the quality of pig iron obtained, with special reference to its suitability—(A) For steel manufacture. (1) Bessemer or Siemens acid process. (2) Bessemer or Siemens basic process. (B) Pig suitable for foundry purposes.

Mr. Harbord gives in detail the whole procedure of the two tests which were made. It is impossible to abstract these data briefly. The chief general result is that so far as the experiments go, they seem to show that the quality of the iron produced in the electric furnace depends upon maintaining the same conditions as in the blast furnace, the only difference being that one is using electrical energy instead of the direct combustion of carbon to produce the necessary temperature. Some important special results of these tests are summarized below in articles 3 to 9 of Mr. Harbord's conclusions. Concerning the cost of the process in comparison with that of the blast furnace, the following different items must be taken into account.

Electrical Energy.—The mean consumption in the two tests was 0.350 e. hp.-years per ton of pig iron. (See also above the figures in Mr. Brown's report.) With improved appliances and larger furnaces, this may be considerably reduced, but for the present it will be safer to take this figure as a basis for calculations. At \$10.00 per e. hp.-year, this is equivalent to \$3.50 per ton of pig.

Electrodes.—According to Mr. Keller, the cost of the electrodes, including the materials, labor, coking, etc., is about \$45.00 per ton, and the consumption is rather below thirty-four pounds per 2000 pounds of pig iron; this is equal to a cost of \$0.77 per ton of pig iron produced.

Coke.—The coke required per 2000 pounds of pig iron is approximately 685 pounds. Taking coke at \$7.00 the cost of the reducing agent is \$2.38 per 2000 pounds of pig produced. In a modern blast furnace, working on a similar ore, the coke required is about 1850 pounds per 2000 pounds of pig iron, costing \$6.40. [After the second experiment, a few charges were made in which the same ore mixture was used, except that the coke was replaced by charcoal. These charges, however, did not work very satisfactorily, as, owing to the ease with which the charcoal oxidized, a large portion burnt away on the top of the furnace, long before it got anywhere near the zone of reduction of the furnace. Mr. Keller is of the opinion that charcoal could be used provided it were first briquetted with the ore, and the briquette broken up to the size of one-inch cubes. Mr. Harbord agrees with him that probably charcoal could be used in this way, and in all probability, if thus intimately mixed with the ore, there would be comparatively little loss by oxidation on the top of the furnace, and the charcoal would do the work of reduction efficiently in the furnace.]

Fluxes.—Mr. Harbord thinks that the cost of lime per ton of iron will be about the same for the electric furnace as for the blast furnace.

Labor.—Mr. Keller estimates that a plant properly equipped for mechanical mixing and charging, producing 100 tons per twenty-four hours, would require sixty men. Mr. Harbord thinks that on starting, a larger number of men would be required, and that for the first year or so it is safer to assume eighty men.

Two estimates are given on the total cost of producing 2000 pounds of pig electrically, these two estimates being those of Mr. Keller and Mr. Harbord respectively. The differences in the two estimates are in the amount of lime and electrical energy required. Mr. Keller assumes 300 pounds of lime and 0.226 hp.-year, Mr. Harbord 400 pounds of lime and 0.350 hp.-year. The total cost without royalty, as estimated by Mr. Keller is \$10.71; that of Mr. Harbord \$12.05. Against this we have the cost in the blast furnace equal to \$11.34. On the basis, therefore, of fuel at \$7.00 and electrical energy at \$10.00 per e. hp.-years, the cost of production in the electric furnace and in the blast furnace is almost the same.

Economical electric smelting is simply a question of the relative prices of fuel and of electric energy. With very high-price fuel, owing to the large amount required—nearly three times that of the electric furnace—the blast furnace is placed at a disadvantage; and, on the other hand, with fuel at anything below \$7.00 per ton, the electric furnace cannot hold its

own. It must be borne in mind that for blast furnace purposes, a hard, mechanically-strong coke must be employed, but for electric smelting, small anthracite, or other small coal or fine coke, provided it is fairly free from sulphur, could be used. Such small coal, anthracite or coke, could probably be obtained at half the price of coke suitable for blast furnaces, and in such cases the reducing agent for the electric furnace would make the cost per ton of pig \$1.00 less. If anthracite collieries were anywhere near, large quantities of small anthracite might possibly be obtained at a very low figure. For the purpose of comparison, it has been necessary to consider the value of the fuel per ton as being the same in each case, but local conditions, such as a good supply of a cheap fuel which is useless for blast furnace work, but suitable for electric smelting, might so reduce the cost of production in the electric furnace as to enable it to compete successfully with the blast furnace. Provided charcoal could be obtained cheaply, it could probably be used if it were briquetted with the ore. Mr. Harbord then makes some brief remarks on electric pig iron smelting, in combination with steel making.

CONCLUSIONS OF MR. HARBORD.

As the result of his investigations into the metallurgy of the electric production of steel and the electric smelting of pig iron, Mr. Harbord gives the following conclusions:

"1. Steel, equal in all respects to the best Sheffield crucible steel, can be produced either by the Kjellin or Héroult or Keller processes, at a cost considerably less than the cost of producing a high-class crucible steel.

"2. At present, structural steel, to compete with Siemens or Bessemer steel, cannot be economically produced in the electric furnaces and such furnaces can be used commercially for the production of only very high-class steel for special purposes.

"3. Speaking generally, the reactions in the electric smelting furnaces as regards the reduction and combination of iron with silicon, sulphur, phosphorus, and manganese, are similar to those taking place in the blast furnace. By altering the burden and regulating the temperature by varying the electric current, any grade of iron, grey or white, can be obtained, and the change from one grade to another is effected more rapidly than in the blast furnace.

"4. Grey pig iron, suitable in all respects for acid steel manufacture, either by Bessemer or Siemens processes, can be produced in the electric furnace.

"5. Grey pig iron, suitable for foundry purposes, can be readily produced.

"6. Pig iron, low in silicon and sulphur, suitable either for the basic Bessemer or the basic Siemens process, can be produced, provided that the ore mixture contains oxide of manganese, and that a basic slag is maintained by suitable additions of lime.

"7. It has not been experimentally demonstrated, but from general considerations there is every reason to believe that pig iron low in silicon and sulphur can be produced, even in the absence of manganese oxide in the iron mixture, provided a fluid and basic slag be maintained.

"8. Pig iron can be produced on a commercial scale, at a price to compete with the blast furnace, only when electric energy is very cheap and fuel very dear. On the basis taken in this report, with electric energy at \$10.00 per e. hp.-year, and coke at \$7.00 per ton, the cost of production is approximately the same as the cost of producing pig iron in a modern blast furnace.

"9. Under ordinary conditions, where blast furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water-power is available, and blast furnace coke is not readily obtainable, electric smelting may be commercially successful.

"It is impossible to define the exact conditions under which electric smelting can be successfully carried on. Each case must be considered independently, after a most careful investi-

gation into local conditions, and it is only when these are fully known that a definite opinion as to the commercial possibilities of any project can be given."

CONCLUSIONS OF DR. HAANEL.

With respect to the above conclusions of Mr. Harbord, Dr. Haanel makes the following remarks.

"Nothing requires to be added to Mr. Harbord's conclusions regarding the electric production of steel; in reference to the production of pig, however, it must be pointed out that

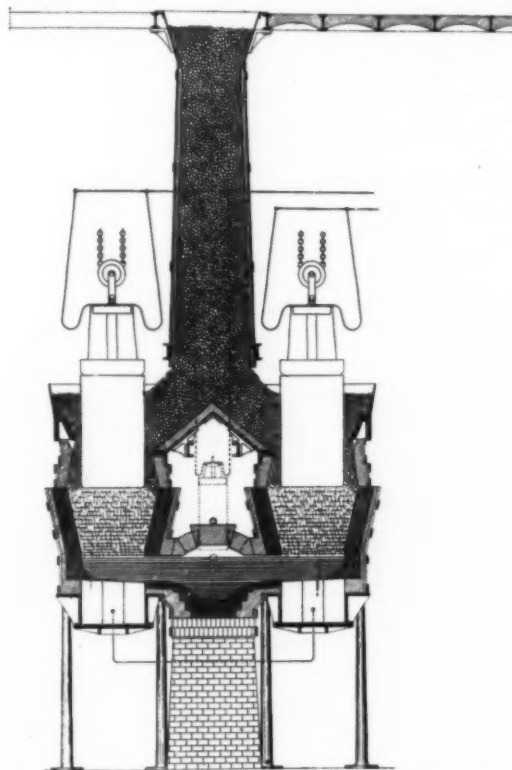


FIG. 4.—IMPROVED FURNACE FOR MELTING PIG IRON.

the results obtained at Livet were results of experiments in furnaces not specially designed for the production of pig from iron ore. With the improved furnace of which drawings are given in Fig. 4, permitting, on account of the higher column of charge, a more effective use of the heat of the resulting gases, and of the reducing power of the CO evolved, a much better figure than the one obtained would result.

"The modern blast furnace, and the different methods for the making of steel as at present employed, are the result of a hundred years of experience, and have reached their present perfection through many modifications, which, in many instances, were accepted and introduced into practice only after much hesitation and opposition. The process of the electric reduction of iron ore must yet be regarded as in the experimental stage; in fact, no plant exists at the present time where iron ore is commercially reduced to pig by the electric process. The more remarkable, therefore, it appears, and the more gratifying it is regarding the future of electric smelting, that experiments made off hand, so to say, in furnaces not at all designed to be used for the production of pig, should give a figure of cost which would enable the experimental plant employed to compete with a blast furnace in regions where electric energy can be had for \$10.00 per e. hp.-year, and where coke is quoted at \$7.00 per ton.

"I am credibly informed that the water power at Chats Falls can be developed at a cost to produce an e. hp.-year at the rate

of \$4.50. There are probably many water powers favorably situated as regards good bodies of ore in the provinces of Ontario and Quebec, which can be developed as cheaply. When such power is owned by the company intending to use it for electric smelting, and peat, coke or briquetted charcoal, made from mill refuse,* which would probably not cost more than \$4.00 per ton, is employed for reduction, the cost of two of the heaviest items entering into the cost of producing pig by the electric process is reduced to one-half.

"When it is considered that the electric process is applicable also to the smelting of ores, such as copper, etc., and that the furnaces are of simple construction, the temperature available 1000° C. above that of the blast furnace, and the regulation of the heat supply under perfect control, it is reasonable to expect that the near future will witness great strides in the application of electric energy to the extraction of metal from its ores, and that familiarity with handling large currents and experience gained in electric smelting will result in solving the difficulties encountered in the smelting of ores, which up to the present time have proven refractory to all economical processes known."

MODIFIED FORM OF KELLER FURNACE FOR MELTING PIG IRON.

In the improved form of the Keller furnace, mentioned above in Dr. Haanel's conclusions and shown in Fig. 4, the interior of the furnace comprises several very distinct parts:

1. At the lower part, the crucible of the furnace in communication with the central crucible connecting the hearths.
2. The boshes of the furnace in the form of a truncated cone expanding towards the top—which constituted the zone of liquefaction of the slag, and of decantation of the metal and slag.
3. The body of the furnace, of an elongated and slightly conical shape, widening towards the base.
4. A hopper of conical form widened towards the top. The upper part of the hearth, just below its junction with the boshes, constitutes the zone of the furnace where the maximum reducing action takes place.

The gas proceeding from the reduction rises in the body of the furnace so that the charge filling this part, already heated, more by caloric conduction than by radiation, from the intense heat at the center of the furnace, comes in contact with the hot gases, producing a partial reduction of the oxide of iron.

The body of the furnace ought, therefore, to be sufficiently high in order that the gases, traversing an adequate thickness of charge, may pass out from the mouth of the shaft, cooled and without pressure. In a final type of furnace Mr. Keller will provide the upper part of the furnace with gas collectors for the purpose of utilizing the escaping gases for the preliminary drying of the charge by making these gases pass in a state of combustion through the charges which carry the charge to the charging hopper.

For the type of furnace proposed for the installation of a plant of 100 tons capacity, the electrodes will be increased to 1.0 meter on the side and an auxiliary electrode will be provided for the central crucible, to be employed to heat the contents of it, in case for any cause there should prove to be danger of the metal setting. (This is already shown in Figs. 1 to 3, above.)

To ensure the continuity of the work, the renewing of the electrodes in the Keller furnace is effected in a few minutes by means of a very simple system of two carriages running on perpendicular rails, and each capable of being placed in the axis of the shaft.

When the replacing of an electrode becomes necessary, the new electrode all prepared and suspended by its own system of elevation, is hoisted on the charging floor of the furnace and brought near the corresponding shaft; the electrode to be removed is brought out and taken away by means of its rolling system. The new electrode is immediately put into the

* In the Ljungberg continuous kiln refuse wood is burnt into charcoal at 33 per cent less cost than in heaps, and with 22 per cent higher yield.

place of the old one. During this time, the source of energy does not undergo any variation on account of the method of distribution employed. In fact, the total intensity, half of which passes into each electrode of the same pole in the normal working of the furnace, passes now into the one electrode remaining alone on this pole during the time of the replacing of the second electrode. This increase of intensity during a few minutes cannot derange in any way the working of the apparatus.

The manipulation of the electrodes and the control of the electric action is effected from a single station on a working platform, where the operator has all the measuring apparatus under his eyes. The operation is so easy that a single man can readily superintend the regulating of a whole battery of furnaces.

Dr. Haanel states that the Commission has been able to observe that the measuring apparatus showed very steady current, and presented only very slight and progressive variations, not necessitating any special skill on the part of the person attending to the regulation.

* * *

In the foregoing we have given as concise as possible a review of the first 116 pages of the volume which deals with the report on the European electric steel and iron processes. Then follows a brief report of a special Commission on the Ruthenburg process of electric smelting of magnetite. This Commission consisted of Dr. E. Haanel and Messrs. Higman and Locke. The Commission which visited the Ruthenburg experimental plant at Lockport in July, 1903, has reached the following conclusion. "From these results it is evident that the reduction of the magnetite, either in the reduction gap of the furnace, or in the soaking pit below the furnace, had been insignificant. Whatever the claims made by the patentee for his process, as exhibited to the Commission, the foregoing results of the investigation demonstrate its entire failure as a process for either agglomerating and fritting the finely-divided ore, or for any useful reduction of the iron ore. The fact that the magnetite loses its magnetism before incipient fusion takes place will prevent the agglomeration of the charge in the pit and the narrow gap between the poles, through which the charge requires to pass, will always render the capacity of the furnace small. These two facts preclude the hope that modifications of the process will render it commercially useful for agglomerating finely-divided ore, in substitution of briquetting."

As an appendix, fully illustrated translations of various valuable papers of French and Italian electrometallurgists are printed, this appendix covering the last 100 pages of the volume. The papers are the following: Henri Harmet on electrometallurgy of iron; G. Gin on the electric manufacture of steel; E. Stassano on his electrothermic process for the reduction of iron ore, and Ch. Vattier on the Keller process of treating copper ores in the electric furnace.

FARADAY SOCIETY MEETING.

The eighth ordinary meeting of the Faraday Society was held Tuesday, October 25, 1904, in the library of the Institution of Electrical Engineers, in London. Dr. F. Mollwo Perkin, treasurer, occupied the chair.

THE MEASUREMENT OF THE POTENTIAL OF THE ELECTRODES IN STATIONARY LIQUIDS. THE DETERMINATION OF CHANGES OF CONCENTRATION AT THE CATHODE DURING ELECTROLYSIS.

Dr. HENRY J. S. SAND read an abstract of his paper on the above subject and illustrated it by lantern views of his apparatus, and of the curves embodying the numerical results of his experiments.

With a view to determine electrode-potentials in solutions,

the concentration of which in contact with the electrode should be known as accurately as possible, a method was elaborated for the measurement of potentials of electrodes in stationary liquids free from convection currents.

The apparatus employed was designed so as to allow the electrode to be placed accurately horizontally at the top or at the bottom, according as the electrolyte becomes lighter or heavier during electrolysis. The liquid connection to the normal electrode is tapped off about 3 to 4 mm. in front of the electrode, the resistance between the junction and the electrode being found either by calculation or else directly by means of a Wheatstone bridge arrangement for alternating currents, partly composed of condensers instead of resistances.

The method was checked by a series of experiments with a copper-sulphate solution, and gave satisfactory results for the diffusion coefficient of copper sulphate. The electrode-potential of a silver solution showed irregularities which are undergoing further investigation.

When two reactions take place, the method may show their successive occurrence by a sharp break in the potential-time curve, analogous to Nernst and Glaser's breaks ("Knickpunkte") in their potential-current curves; the conditions existing at the electrodes are, however, more definitely known than in the "Knickpunkt" method. An alcoholic solution of cuprous chloride which had become partially oxidized to cupric chloride showed such a break corresponding to the processes: reduction of cupric chloride and deposition of copper.

When acid solutions of nitrobenzene were electrolyzed the time-potential curves showed characteristic retrogressions of potential after a definite time, possibly corresponding to changes in the condition of the cathode.

From experiments on alkaline solutions of nitrobenzene a lower limit for the diffusion coefficient of nitrobenzene in the solutions experimented upon was calculated, and it was shown that Haber's results regarding the dependence of electrode-potential on current-density cannot be explained by concentration changes at the electrode. This result is of great interest in connection with the fundamental question whether electrode processes are of a reversible nature; that is, whether on the boundary between electrode and electrolyte, chemical equilibrium must be supposed to remain continually established.

The matter may also be stated in the following manner, corresponding to a form in which it has recently been put forward by Nernst as a general principle; differences of chemical potential cannot exist for a finite period of time on the boundary of two phases, that is "between infinitely near points," as this would lead to infinitely great forces and reaction velocities. According to this assumption the actual velocities of electrochemical reactions and all others which occur on the boundary of two phases, are infinitely great as soon as conditions of equilibrium have been overstepped by a finite amount, the observed velocities being simply limited by the rate with which diffusion and convection renew the material removed by the reaction. As conditions of equilibrium in electrochemical reactions are determined by the electrode-potential (i. e., the drop of electromotive force on the boundary between electrode and electrolyte), and the rate of these reactions is proportional to the current strength, this may be expressed in the following manner: "When the electrode-potential at which a reaction begins has been exceeded by a finite amount, the current strength becomes independent of it, being only limited by the velocity of convection and diffusion."

Several experimental facts conform to this rule. However, the principle seems sufficiently invalidated for *a priori* application to actual cases owing to the impossibility of stating that the atoms chemically reacting on the boundary of two phases are in infinite proximity. In fact the results of sev-

eral recent researches, notably those of Haber stand in opposition to conclusions drawn from the principle under discussion. The object of all these researches is the investigation of the dependence of electrode-potential as defined above on current-density. In Haber's work the reduction of nitrobenzene was examined, but instead of finding the current-density to be independent of the potential of the cathode, his results point to a logarithmic dependence of the latter on the former. In fact he has partially explained his results, starting from the not improbable assumption that the variations of potential are brought about by the absorption in varying concentrations of hydrogen, or other reducing material, by the electrode. In the further elaboration of this view his results may all be foretold, if we adopt as an empirical fact that the velocity of reduction at the electrode v depends on the concentration of hydrogen c in it according to the relation $v = kc^m$, in which k and m are constants depending on the conditions of the experiments.

In contradiction to this, Nernst's view would require that once the conditions of equilibrium have been overstepped, the above velocity should be infinitely great. As a matter of fact, Haber's results have been doubted by Brunner, who believes that changes of concentration in the liquid adjoining the electrode may be partly responsible for them. To this Haber and Russ have replied, stating reasons for the correctness of the results obtained by the former. Now, it is important that the present author arrives at the result that the variations of the electrode-potential with current-density observed by Haber cannot be explained as the result of concentration changes at the cathode.

In the discussion which followed, Dr. F. M. Perkin referred to the great practical importance of potential measurements; for example, in oxidation or reduction processes slight differences in the potential often mean very great differences in the amount of energy absorbed. Prof. Threlfall said that there was too much uncertainty, due to unknown changes, in complex phenomena such as had been investigated by the author, for the experiments to yield a definite and finite answer. More valuable results might be looked for at the present stage of knowledge if the simpler problems in electrolysis—familiar difficulties that occurred in one's daily practice—were attacked. As regards the experiments themselves, he thought that the method of employing a capillary tube in connection with the cathode for measuring electrode-potentials, would yield as accurate results as those obtained by the author. Dr. Sand, in reply, said the chief purpose of his work was to show the applicability and limits of his method, although he felt the force of what Prof. Threlfall had said. The capillary tube method was useless in experiments like these, which were really diffusion experiments, as he particularly wished to avoid convection currents.

A SUGGESTED NEW SOURCE OF ALUMINIUM.

Miss BUENA POOL presented a paper in which she called attention to the work of Messrs. Holland and Warth, a fuller account of which may be found in the Geological Magazine for 1903.

While practically all the aluminium produced at the present day is made from bauxite, of which the British Isles possess but scanty deposits, the authoress pointed out that in India there is a vast treasure-house of aluminium in laterite deposits spread over the surface of thousands of square miles of country waiting for the spade of the prospector. The laterite deposits of India have long been a puzzle to geologists. They occur spread over vast areas as a purely superficial deposit of depths varying from a few feet to a few hundreds of feet, chiefly over the Deccan trap area of Central India. Until recently, laterite, in consequence of its appearance and consistency, was loosely classed as a clay; recent careful investigations and analyses seem to show, however, that it is much more closely analogous to bauxite, the alu-

minium being present in the hydrated form, and not as silicate.

Four distinct classes of laterites are described in detail. From specimen analyses which are quoted, it would appear that the high-level laterites in particular bear an obvious and striking resemblance to ordinary bauxite. The low-level laterites contain much free silica and clay. The conclusion of the paper is that these Indian bauxites have all the characteristics to render them commercially valuable; their purity, ready accessibility, widespread occurrence at all elevations, and association with flowing water, pointing them out as an almost perfect source of aluminium.

Analyses of six specimens of high-level laterites follow; with the exception of two specimens with admixed quartz sand, they show very little silica.

	Marwara.	Makab.	Sartara.	Nilgiris.	Karad.	Satara.
H ₂ O	26.82	24.99	23.88	20.70	11.82	14.39
Quartz, SiO ₂					1.77	....
SiO ₂	3.90	.72	.37	3.14	4.23	.90
TiO ₂ .....	.38	.42	4.45	....	.10	1.59
CaO .....	.35	....	.86	....	.52	.64
MgO .....	....	....	....	....	trace.	.20
Fe ₂ O ₃	13.75	23.41	26.61	37.88	51.25	56.01
Al ₂ O ₃	54.80	50.46	43.83	38.28	30.86	26.27
	100.00	100.00	100.00	100.00	100.00	100.00

Molecules of Water from one Molecule of Aluminium.

	2.80	2.83	3.11	3.09	2.19	3.13
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The resemblance of these analyses to those of ordinary bauxite is obvious and striking. A general property of these high-level laterites is their infusibility before the blow-pipe. This serves to distinguish them from the low-level or detrital laterites.

In the discussion which followed Mr. W. Murray Morrison said that gibbsite (Al₂O₃ + 3H₂O, found at Kodikanal) could not be used as a direct source of aluminium, without being first treated for alumina. He did not think that the Indian laterites were likely to be used in England at present, as there is a plentiful supply of French bauxite to draw from, but, of course, they might, in time, be worked in situ. There was as yet no great demand for aluminium in India.

ELECTROLYTIC OXIDATION OF HYDROCARBONS OF THE BENZENE SERIES.—PART I. HYDROCARBONS CONTAINING THE METHYL GROUP.

Dr. F. MOLLWO PERKIN gave a short account of a paper by himself and Mr. H. D. LAW on the above subject. Owing to the more or less fragmentary style and the incompleteness of the literature dealing with the electrolytic oxidation of organic substances, the authors have commenced a detailed study of the electrolytic oxidation of hydrocarbons of the aromatic series.

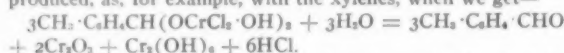
They find that when an emulsion of toluene and dilute sulphuric acid or caustic alkali is electrolyzed the whole of the toluene is burnt up, but that when a mixture of acetone and toluene is electrolyzed in the anode compartment of a cell, benzaldehyde is produced. Unless, however, a large excess of acetone is present the yield of benzaldehyde is very small—even under the best conditions they were unable to obtain more than about eight per cent of benzaldehyde. The conditions employed were 550 to 600 cc. acetone, 50 grams toluene, and 250 cc. of dilute sulphuric acid. Beside benzaldehyde a small quantity of another product was produced which may be benzyl alcohol or a condensation product of the molecules of the toluene. They further oxidized ortho-meta- and para-xylene and mesitylene and pseudo-cumene under similar conditions. In each case the corresponding mono-aldehyde

was produced, with, on occasion, small quantities of the dialdehyde. Small quantities of a neutral product were also obtained, which are under examination. In no case was the corresponding acid produced. In the case of ortho- and para-xylene the yield of aldehyde was from 25 to 35 per cent. With the meta-xylene the yield was not above 10 per cent. Contrary to experience in ordinary chemical oxidations, the meta-xylene seems to show a greater tendency to be burnt up than the ortho- and para-xylenes.

With mesitylene and pseudo-cumene, the mono-aldehydes were also produced. With the latter substance, apparently a mixture of the three possible isomers. Further experiments are in progress, and the authors are also investigating hydrocarbons of the benzene series containing other groups than the methyl group and hydrocarbons containing mixed groups.

The interesting fact that the work of the authors has elucidated is that electrolytical oxidation, when carried out upon hydrocarbons of the benzene series, dissolved in an appropriate solvent, is not so energetic or so far-reaching as when these substances are oxidized with ordinary oxidizing agents, such as potassium permanganate and nitric or chromic acids. Now, in oxidizing hydrocarbons containing a methyl group, there are three possibilities. The first stage would result in the formation of an alcohol, the second in the formation of an aldehyde, and the third stage in the production of an acid. In hydrocarbons of the benzene series there is the further possibility of the benzene ring being split and the entire substance being burnt up.

With most chemical agents the oxidation proceeds directly to the third stage, and an acid results. By oxidation with chromyl chloride it is possible to produce the aldehydes, an addition product of the aldehyde being produced, which afterwards can be decomposed with water, when the aldehyde is produced, as, for example, with the xylenes, when we get—



Ellis has shown that, when p-nitrotoluene is dissolved in acetic and sulphuric acids and subjected to electrolytic oxidation, nitrobenzyl alcohol is the main product. Renard and others have obtained small quantities of benzaldehyde by the electrolytic oxidation of toluene dissolved in alcohol. The authors have now carried this work further, and have shown that, when toluene, the xylenes and mesitylenes are dissolved in acetone and subjected to electrolytic oxidation, the main product produced is the mono-aldehyde. It is very interesting to note that, so long as there is any unchanged hydrocarbon present, the oxygen attacks it in preference to the aldehyde. In fact, the aldehydes, strange to say, do not appear to be readily oxidized by anodic oxygen.

Another fact to be noticed is that, with hydrocarbons containing more than one methyl group, only one group is attacked, and there appears very little tendency for the other group to be acted upon until the whole of the hydrocarbon has been converted into the mono-aldehyde.

The position of the group also seems to have a determining action; when the group is in the ortho- or para- position the yield of aldehyde is higher than when it is in the meta-position.

It appears as if the hydrocarbon containing the group in the meta-position has more tendency to be completely burnt up than when the group is in either of the other positions.

In the case where there are three methyl groups present it appears that all the groups are more or less attacked, although only a mono-aldehyde is produced. With mesitylene, in which the groups are symmetrical, this did not lead to any difficulties. But in the case of pseudo-cumene, a mixture was obtained.

Although the chief product of oxidation is the mono-aldehyde, there is also a varying quantity of a neutral substance obtained, which may be the corresponding alcohol; but, as a portion of it boils at a very high temperature, the authors think it may be a condensation product, and that they may have obtained a styrol-like compound.

Mr. Frank Shedden, in a written communication, suggested the use of a gas-tight cell, and determining the amount of carbon dioxide given off to show the extent of any "burning" that might be taking place. He asked whether the authors had lowered the current density by increasing the anode surface. Dr. Perkin said that they had begun to make a study of the gases evolved. Their anodes were of platinum, so they had only used small ones. The chief difficulty they wished to overcome was the formation of tarry products owing to the concentration of H_2SO_4 in the anode chamber after a time. Neutralization or withdrawal of solution were both out of the question.

ELECTRIC FURNACE METHODS IN IRON AND STEEL MANUFACTURE IN COMPARISON WITH THE ORDINARY METALLURGICAL PROCESSES.

BY PROF. B. NEUMANN, PH. D.

Practically all the various methods and apparatus in which the electric current is used to produce iron from ores, or to change pig iron into steel, or to manufacture high percentage ferro-alloys, have been described in previous issues of *ELECTROCHEMICAL INDUSTRY*; these articles also contain some figures, given by the inventors, on the power consumed in their processes.

In a long paper¹ in *Stahl und Eisen* I have discussed the use of the electric furnace for iron and steel production and have investigated the applicability of the different methods with respect to the quality of the product, and with respect to the power consumption. I have studied especially the question what the prospects are in the main iron countries (United States, Germany and England) for these electric furnace processes in comparison with the ordinary metallurgical processes, such as the blast-furnace process, the Bessemer and Martin processes, the crucible-steel process, etc. The results which I have reached should, I think, be of interest also to the readers of this journal.

The different electric furnace processes may be classified in two groups: First, those which produce only pig iron and alloys; second, those which change pig iron into steel; but this classification cannot be sharply made since Stassano² and Conley³ use apparatus in which the reduction to pig iron and the refining process are simultaneously carried out. Keller,⁴

PROCESS	Stassano		Heroult		Kjellin		Ferro-silicon
	A	B	C	D	E	F	
Number of samples.....	5	2	2	1	8	3	3
Mn	0.068—0.272	0.09 —0.092	0.092—0.138	0.000	0.13 —0.54	0.33 —0.49	0.16—0.86
Si	0.018—0.048	trace	0.020—0.023	0.007	9.03 —0.85	0.35 —0.42	25.0 — 25.0
S	0.046—0.130	0.05 —0.059	0.016 —0.022	0.008	0.005—0.03	0.01 —0.015	0.01— 0.04
P	0.005—0.060	0.009—0.029	0.006—0.011	0.003	0.009—0.014	0.011—0.014	0.04— 0.12
C	0.084—0.120	0.090—0.17	0.840—1.080	0.008	0.08 —1.70	0.95 —1.45	0.23— 0.48

¹ *Stahl und Eisen*, 1904, pp. 682, 761, 821, 883, 947.

² *ELECTROCHEMICAL INDUSTRY*, v. I., pp. 247, 461.

³ *ELECTROCHEMICAL INDUSTRY*, v. I., p. 427.

⁴ *ELECTROCHEMICAL INDUSTRY*, v. I., pp. 162, 421.

Héroult⁵ and Harmet⁶ use different apparatus for these two processes; while Kjellin,⁷ Gin⁸ and Girod⁹ only refine the metal. The process of Ruthenburg¹⁰ is not a real melting process, but is rather a briquetting method by which sintered, half-reduced products are obtained. Of the apparatus used for these purposes, those of Stassano, Keller, Héroult, Harmet and Conley employ carbon electrodes, while those of Kjellin, Schneider, Gin and Girod do not use carbon electrodes. Concerning the details of the furnace construction the reader may be referred to their description in previous issues.

In order to arrive at a proper estimate of the value of a technical process, the quality of the products is of great importance. It is to be regretted that with respect to this point not sufficient data are at the disposal of the writer for most processes. Some of them are not yet used on a large scale, while in other cases the inventors have not placed samples of their products at the disposal of the writer.

Concerning the chemical constitution of the products the table on page 488 gives some figures.

The following remarks may be made on the figures in this table; A are figures from the committee-report of Lucchini; B are figures of Goldschmidt; C are figures of analyses of tool steels; D of soft steel, the figures being given by the inventor; E gives figures of Gysinge steel from a paper of Benedicks; F figures of Stead; G are analyses of commercial products. Concerning products of Keller, the author has not data.

As to the physical properties of these products of the electric furnace, little is known. According to Lucchini, Stassano-metal contains too much sulphur to be forged when hot. On the other hand, Goldschmidt calls it a product similar to Martin steel. The writer has no data on the tensile strength of the steel made by Stassano and Héroult. Bertolus states that Keller steel may be compared with Martin and Bessemer steel. A forged and tempered sample gave 83.4 kg. per square millimeter tensile strength with 13 per cent elongation.

Very detailed tests of the mechanical properties of Gysinge steel have been made by A. Wahlberg.¹¹ With non-tempered samples of 0.7 to 1.2 per cent carbon, the tensile strength was 87 to 118 kg. per square millimeter, with 11.6 to 4.3 per cent elongation. With tempered samples of 0.7 to 1.2 per cent carbon the tensile strength was 73 to 85.4 kg. per square millimeter, with 14.6 to 11.1 per cent elongation.

With respect to homogeneity of structure the castings were equivalent to the best Swedish steels. The same may be said of the tensile strength and bending strength in comparison with Oesterby crucible steel. The resistance against concussion is even greater for electric steel.

The high-percentage ferro-alloys made in the electric furnace are superior to those made in the blast furnace, on account of greater purity and lower content of carbon. Moreover, the electric furnace enables the manufacture of higher-percentage alloys than the blast furnace; this is true as well for ferro-silicon, as for ferro-tungsten, ferro-titanium, ferro-chromium, etc.

In the ordinary metallurgical processes for reducing iron from ores, and for changing pig iron into steel, the energy required for the different reactions and physical changes is generally obtained by burning carbon (an exception being the Bessemer process). On the other hand, the electric furnace process tries to utilize electricity instead of carbon for heat production. Since electric energy is a very expensive form of energy, the power consumption of the processes and the heat efficiency of the apparatus, together with the price of electrical energy, are of decisive importance for the economical application of the processes.

To reduce one metric ton (1000 kg.) of iron from pure

Fe_2O_3 , 357.8 kg. of carbon are required; while 317 kg. are required for reduction from Fe_3O_4 . The reduction from oxide consumes theoretically 1,213,139 calories, which can be replaced by 1403 kw.-hours. For the reduction from ores it is to be considered, however, that besides the reduction of iron to the metallic state, heat is consumed for the reduction of impurities, for heating the additions, for melting the slag, for heating the iron bath, for making up the losses due to radiation, and for the heat escaping with carbon oxide. If one calculates for an example of ore thermochemically the quantity of heat required, the result is about 2000 kw.-hours.

Now the question comes up what is the efficiency of the electric furnace and what are the other losses during operation on an industrial scale? Goldschmidt calculates an efficiency of 61 per cent for the Stassano furnace, while J. W. Richards found that electric furnace processes, in which the charge is heated with fusion and with chemical reactions, have an efficiency of 60 to 75 per cent. To reduce pig iron from the ores on an industrial scale, one would therefore have to expect a consumption of about 3000 kw.-hours per ton of metal. This figure agrees approximately with the following experimental results and calculations.

Stassano consumes 3155 kw.-hours per 1000 kg. of metal with the use of pure hematite; Rossi 3354 kw.-hours with titaniferous ores; Keller gives the figure 2800 kw.-hours; Sjoestedt, when working on a small scale with roasted pyrrhotite, used 3100 to 3500 kw.-hours; Harmet calculates about 2600 kw.-hours, but he gives too low a figure for the loss by radiation; if his figure is properly corrected, one gets 3270 kw.-hours. An average value of 3000 kw.-hours, as assumed above, is therefore certainly not too high.

For the manufacture of ferro-silicon 5000 kw.-hours (Gin) and 3500 kw.-hours (Keller) are stated to be required. This large difference may, perhaps, be explained by differences in the constitution of the charge.¹²

For changing pig iron into steel, nearly all electrical processes employ a method similar to the ordinary open-hearth process. The amount of carbon contained in the pig iron is reduced by addition of wrought iron or scrap steel, and is often still further reduced by adding some iron ore. In this method, therefore, the electrical energy supplied to the furnace is to furnish only the heat required for melting the charge and for maintaining the temperature necessary for the refining process. The thermochemical calculation gives 378,360 calories or 438 kw.-hours, when starting with molten pig iron, and 753,560 calories or 871 kw.-hours when starting with cold pig iron.

For the operation on the industrial scale the following figures are given. When starting with molten iron, the number of kw.-hours required is 620, according to Harmet, 694 according to Keller, 600 according to Gin. When starting with the cold charge, the number of kw.-hours is 920 according to Conley, 882 according to Héroult, 966 according to Kjellin. Héroult's figure is very low, but it may be that the conditions are here different on account of the preliminary treatment of the metal bath. The average of real energy consumed is 900 to 950 kw.-hours per ton of steel.

The figures of the cost of operation given by the inventors do not permit a fair comparison for the reason that the cost of materials and the cost of power vary from place to place.

If the problem is to find for a certain district the cost of the electric process, and to compare it with the cost of the present metallurgical process, one has to consider that ore, additions and reducing material are the same for both processes with respect to their nature and quantity. The difference consists in the fact that the heat produced by carbon or coke is replaced by electrically generated heat. If we further assume that the cost of repairs and the wages of attendants are the same in both cases, the question is reduced to a com-

⁵ ELECTROCHEMICAL INDUSTRY, v. I., pp. 64, 449, 287, 467.

⁶ ELECTROCHEMICAL INDUSTRY, v. I., pp. 422, 589.

⁷ ELECTROCHEMICAL INDUSTRY, v. I., pp. 141, 377, 577.

⁸ ELECTROCHEMICAL INDUSTRY, v. II., p. 20.

⁹ ELECTROCHEMICAL INDUSTRY, v. II., p. 300.

¹⁰ ELECTROCHEMICAL INDUSTRY, v. I., pp. 84, 202, 483.

¹¹ *Jer. Annal.*, 1902, p. 296; *Stahl und Eisen*, 1904, p. 824.

¹² Concerning this point, see the article of Dr. G. P. Scholl, page 396 of our October issue.—Ed.

parison of the cost of a certain quantity of coke with that of the electrical energy equivalent to it.

The prices are as follows: Coke in the United States (Connellsville) \$4.00, England \$4.00, Germany \$3.75, France (Livet) \$8.00, Chili \$20.00, Brazil \$12.00. The cost of power in the United States (from water-power, at Niagara Falls) is, according to J. W. Richards, \$20.00 per hp.-year, or \$27.20 per kw.-year, or 32 cents per kw.-hour. If the cost is \$15.00 per hp.-year, it is \$20.40 per kw.-year, or 24 cents per kw.-hour. In Germany electrical energy, produced from blast furnace gases or from water power, is \$20.00 per hp.-year. In the Alps electrical energy, developed from water power, costs \$7.50 to \$10.00 per hp.-year; in Chili \$6.00, according to Keller.

Let us assume, for instance, a hematite ore, then there are required for reduction 413 kg. of carbon, for heating 566 kg., the latter quantity corresponding to 662.3 kg. of commercial coke, in the value of \$2.65. On the other hand, for producing the same quantity of heat electrically by the processes so far proposed, there are at least required 2688 kw.-hours, which cost \$6.45 to \$8.60. To this is to be added \$2.50 to \$3.50 for consumption of electrodes. The electrical production of pig iron would, therefore, cost in the United States \$6.50 to \$9.00 more than the ordinary metallurgical process. The situation is exactly the same in Germany and England, even if other ores are used, but the calculation comes out quite differently if based on the conditions in Chili or Brazil. There the coke would cost \$12.00 and \$7.50, respectively, the electrical energy \$1.75 and \$1.50. Of course, there is to be added \$5.00 or \$6.00 for electrodes and \$7.70 or \$4.60, respectively for coke for reduction (against \$1.60 in the United States). Anyhow, this example shows that the electric reduction of pig iron from ores may be possible in countries where fuel is scarce and waterpowers plentiful, while it is commercially impossible in the main iron countries.

In steel manufacture the charge and additions are also the same for both cases. The open hearth furnace produces one ton of steel with 220 to 250 kg of carbon, the electric furnace with 950 kw.-hours. There is, therefore, a cost of 55 cents to 60 cents for carbon, against \$3.00 for electrical energy. The open-hearth furnace is, therefore, cheaper by about \$2.50 per ton in the United States than the electrical furnace.

Kjellin and Benedicks, in Gysinge, have made in the electric furnace a fine crucible steel in the value of \$42.90. They started with fine raw materials, the cost of the charge being alone \$32.50. It is not probable that the fine material for the charge may be had cheaper at other places, while the cost of power at Gysinge corresponds approximately to that in United States and Germany. For these countries we may, therefore, assume the same cost of operation is in Gysinge. With the present crucible steel process there are required 35 to 40 crucibles per ton of product, and these crucibles stand only 3 to 5 heats, while 1200 kg. of carbon are used per ton. The cost of melting and the cost of crucibles is therefore about \$12.00 to \$17.00. With the Gysinge furnace, one ton of steel can be obtained in one single operation. The cost for brick work and repairs is \$2.08, the cost of power \$5.00, so that in this case the electric process is essentially more economical than the old crucible process. For refining steel the electrical process can, therefore, compete with the old crucible steel process in the main iron countries.

To sum up, we should expect that in the United States the blast furnace will continue to be used for reducing pig iron from ores, the open-hearth furnace and the Bessemer converter for making the ordinary steels, while only for making special steels and high-percent ferro-alloys the electric furnace can be used economically.

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The production of iron ore in the United States was 35,019,308 long tons in 1903.

MATERIALS FOR RESISTORS.

By FRANCIS A. J. FITZGERALD.

The word "resistance" in its application to electricity has two meanings: (1) It connotes a property of a substance, and is used either in a qualitative or quantitative sense; (2) it is applied to the resistant substance itself. In writing the following article it was sometimes found necessary to resort to various circumlocutions for the purpose of avoiding such clumsy expressions as "the resistance of the resistance," and sometimes the reader was called upon to use an unnecessary mental effort to discover whether the word "resistance" meant the property of a substance or the substance itself. It therefore seemed advisable to use the word "resistor" to connote a substance used because of its property of offering resistance to the passage of an electric current, and to reserve the word "resistance" for the property either in a qualitative or quantitative sense.

So far as the heating of the charge in furnaces by resistance is concerned, the most elementary form is that in which the charge itself forms the resistor. Examples of this type are found in Acheson's graphite furnaces and Gin's steel furnace.

In theory, at least, the latter is the more simple, for the resistor consists of molten iron at an initial temperature of 1300° C. This is fed into a long canal, and is raised to maximum temperature of about 1900° C., and is eventually poured at a temperature of 1600° C. The total change of temperature in the resistor amounts, therefore, to 600° C., and apparently this does not produce any marked effect on the resistivity of the iron, since nothing is said about it in the published descriptions of the Gin process.

The conditions became more complex in Acheson's graphite furnaces. In these furnaces the resistor is composed of a mass of cold carbon which is raised to the highest attainable temperature, and there is thus produced a great change in resistance. In addition to the change in resistance caused by the increase in temperature there is a further diminution of resistance brought about by the conversion of the amorphous carbon into graphite. This is illustrated by the curve in Fig. 1, where



FIG. 1.—CHANGE OF RESISTANCE OF GRAPHITE FURNACE.

the ordinates are the ratio of the electromotive force E to the current I and abscissæ are the time. It will be observed that after the lapse of a certain time — becomes

constant, that is, there is no further change in the resistance, and consequently the conversion of the carbon to graphite is complete. A curious characteristic of the curve is the increase of resistance near the beginning. A possible explanation of this will be discussed later.

If it is assumed that the ratio of the resistivity of carbon at ordinary temperatures to that of carbon at the temperature of the graphite furnace is 2; that the ratio of the resistivity of amorphous carbon to graphite is 4, and, finally, that the change of resistivity produced in graphite by heating to any temperature is proportional to the change produced in amorphous carbon by the same means, then the ratio of the initial to the final resistance of the resistor in the graphite furnace is 8. In some cases this probably approximates actual conditions, but, as will be shown later, various factors enter into the determination of the resistance of a carbon resistor.

In order to work economically with an electric furnace it is usually important that the maximum power available be used throughout the furnace run, and if the resistor changes its resistance it is necessary to provide some means of regulating the voltage. In any furnace of this type let the initial

resistance of the resistor be R_1 , the final resistance R_2 , W the watts required for heating the furnace, E_1 the maximum voltage, and E_2 the minimum voltage required, so that W watts are used throughout the run. Then,

$$\frac{E_1^2}{W} = R_1 \quad (1)$$

$$\frac{E_2^2}{W} = R_2 \quad (2)$$

dividing (1) by (2)

$$\frac{E_1^2}{E_2^2} = \frac{R_1}{R_2}$$

$$\text{whence } \frac{E_1}{E_2} = \sqrt{\frac{R_1}{R_2}} \quad (3)$$

Equation (3) therefore shows that in order to use the full available power throughout the run, the maximum and minimum voltages attainable must have to each other the ratio of the square roots of the maximum and minimum resistances of the resistor.

In furnaces like those used by Héroult, Keller, etc., for the manufacture of steel, where the resistor consists of a molten slag into which the terminals dip the regulation of the power used is effected by the depth to which the terminals are immersed in the slag. In such furnaces, however, relatively low temperatures are used. In furnaces where high temperatures are required, the resistor is usually composed of carbon, so that an exhaustive examination of that substance in this connection is desirable.

It must first be observed that the resistivity of carbon is reduced by about 50 per cent when it is heated to a high temperature. Assuming, therefore, that no other change is produced and that the resistor in a furnace is composed of carbon, then, if it is desired to use the furnace at its full power capacity throughout the run, it follows from equation (3) that the ratio of the maximum and minimum voltages required is given by

$$\frac{E_1}{E_2} = \sqrt{2} \\ = 1.41$$

If, however, the temperature of the resistor is higher than the carbon composing it has ever been at before, another factor enters in. The physical state of carbon is permanently changed by heat. Thus, when carbon is raised to a higher temperature than it has ever reached before, its density is increased; its heat conductivity is increased; its electrical resistivity is decreased; its resistance to oxidation is increased; its resistance to disintegration in certain solutions is increased. The change that concerns us at present is the decrease in electrical resistivity.

An experiment designed to illustrate this phenomenon was made by heating one end of a carbon rod to the highest attainable temperature in an electric furnace, while the other end remained at the temperature of the room. The intermediate part of the rod was covered with a heat insulator, so that there was a gradual fall of temperature along the rod. After heating as described, the rod was divided into sections by a number of lines drawn 1 centimeter apart and connected in series with an ammeter in a circuit giving a constant e. m. f. The drop of voltage along the sections was then measured by means of a millivoltmeter. As the resistance of the latter was rather low it was difficult to avoid errors due to making poor contact between the leads from the voltmeter and the rod. Five observations of the voltage drop along each section were made and the average and percentage average deviation calculated. The maximum percentage average deviation was 1.6, and the mean of the percentage average deviations was 0.67. The total variation of the current during the experiment was 1.1 per cent, and was an increase due to the heating of the rod and consequent lowering of its resistance. The

results obtained, therefore, are not accurate but sufficiently satisfactory to give an approximate idea of the change in resistivity produced by heat.

From the observations the conductances of the different sections of the rod were calculated and the results plotted so as to give the curve shown in Fig. 2, where the abscissæ are distances in centimeters from the cool end of the rod, and the ordinates are conductances.

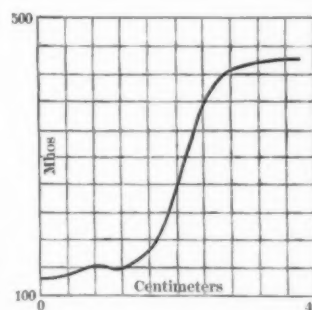


FIG. 2.—CHANGE OF CONDUCTIVITY ALONG CARBON ROD.

The curve is somewhat misleading, for it might appear at first sight that at first the change in conductivity was gradual with increased temperature, and afterward was rapid. This conclusion would be erroneous, for the abscissæ are distances from the cool end of the rod, and equal increases in distance do not necessarily mean equal increments in temperature. As the end of the rod in the interior of the furnace is raised in temperature the physical properties of the carbon are changed, as already described, therefore the heat conductivity of that part of the rod is greater than that of parts near the cool end. Hence the fall of temperature along the hotter parts of the rod is more gradual than along the parts further removed from the hot end. Moreover, there are other changes going on in the rod which must affect the temperature gradient. At one part silica is reduced and silicon carbide formed, at another various substances are vaporizing or condensing, and so forth.

The practical conclusion to be drawn from this phenomenon of the permanent change of resistivity produced in carbon by high temperature is that before using it as a resistor it should be raised to the maximum temperature to which it will be submitted in practice. Of course, this is not absolutely necessary, for in any furnace where a certain temperature is required in the resistor, the carbon may be raised to that temperature the first time the furnace is run. Nevertheless, in most cases it will be advantageous to make the resistor of carbon that has already been heated to as high or a higher temperature than that required.

The best plan is to use graphitized carbon for that form of carbon may be described as stable in its physical characteristics, so that the only change that is experienced when using it as a resistor is temporary and due to the increase in temperature.

In addition to the physical change occurring in carbon when heated to a high temperature, there are chemical changes if, as usually is the case, there are impurities present. Referring again to the conductance curve of Fig. 2, it will be observed that at a point about 10 centimeters from the cool end of the rod there is a decrease in the conductivity. Examination of the ash of the carbon at this point showed that amorphous silicon carbide was formed, and that might easily explain the decrease in conductivity. This would also account for the very gradual increase in the conductivity towards the cool end of the rod.

Such an explanation seems to be confirmed by the determinations of the densities of the carbon composing the sections of this part of the rod, for these show a rapid increase.

A similar explanation is offered for the increase in resistance observed in the resistance curve of the graphite furnace (Fig. 1).

In view of this effect it seems advisable to use pure carbon in the construction of resistors where the temperature at which they are used is high enough to cause the formation of carbides.

The next thing to be considered is the kind of carbon to be used as a resistor. It has already been shown that the carbon used should be in the form of graphite; but the properties of carbons that have been raised to the graphitizing temperature vary greatly, according to the kind of amorphous carbon used. For example, the different properties of carbon rods made from petroleum coke and lamp black have been described elsewhere:

"Two carbon electrodes were placed side by side in the electric furnace. One of these electrodes was made of the purest lamp black carbon, the other of petroleum coke, with the addition of about 2 per cent of ferric oxide. After removal from the furnace the electrodes were compared, with the following results:

Lamp Black Electrode.

Does not show any of the ordinary evidences of graphitization. The color of the carbon is unchanged, and it is still hard and brittle when an attempt is made to cut it with a knife. It will scarcely mark paper and will not take a brilliant polish when rubbed.

Density 2.05.

When used as anode in electrolyzing a solution of sulphuric acid the disintegration is very rapid.

Burns with comparative ease when heated to bright redness in the air. In quantitative test it was found that the rate of oxidation was nearly 100 per cent greater than that of the petroleum coke electrode.

Treated with the oxidizing mixture of potassium chlorate and nitric acid the specimen was converted into graphitic oxide.

Petroleum Coke Electrode.

Has brilliant graphitic appearance. Can be readily cut with a knife. Takes a brilliant polish when rubbed. Marks paper like a pencil.

Density 2.20.

When used as anode in electrolyzing a solution of sulphuric acid the disintegration is much slower than in the case of the lamp black electrode.

Burns with difficulty when heated to bright redness in the air.

Treated with the oxidizing mixture of potassium chlorate and nitric acid the specimen was converted into graphitic oxide.

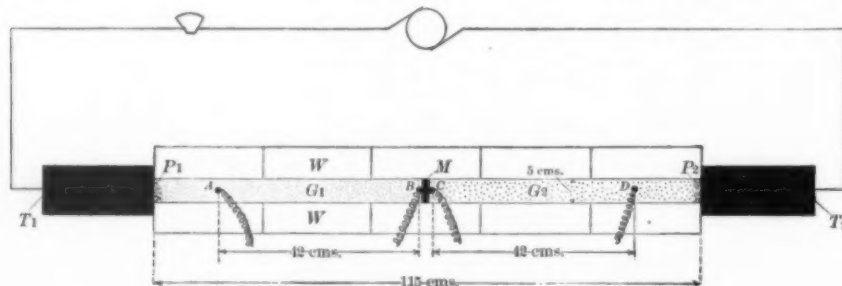


FIG. 3.—TEST OF GRANULAR CARBON RESISTORS.

"Applying Berthelot's definition, both of the specimens are graphite; but it will be observed that they differ in every respect, save in the one property of forming graphitic oxide."¹

This shows very plainly that even when carbon is raised

¹ Monographien über angewandte Elektrochemie XV, Band. "Künstlicher Graphit," von F. A. J. FitzGerald.

to the graphitizing temperature its properties will depend largely on the kind of amorphous carbon used, and that by choosing different kinds of carbon we may get variations in resistivity which are useful in the construction of resistors. As an extreme example, it is obvious that the resistivity of petroleum coke and retort carbon will be very different, even after heating both of them to the temperature of the graphitizing furnace.

Usually a solid carbon rod is not a satisfactory resistor, particularly if working on a large scale, since to generate energy at a sufficiently rapid rate to obtain a high temperature it is necessary to use a current of great amperage and low e. m. f. But if the carbon is broken up into many pieces the resistance of the mass is greatly increased, because of the number of points of contact which have a high resistance. It is evident that if the number of points of contact is increased the resistance of the resistor will be increased, other things being equal. This brings us to the discussion of granular carbon as a material for the construction of resistors.

If a mass of granular carbon is placed loosely in a trough, the ends of which are formed of carbon blocks connected with a source of current, a number of minute arcs are formed at the points of contact of the grains of carbon, and the whole mass soon becomes hot if the rate of development of energy in the circuit is sufficiently high. If, instead of putting the granular carbon loosely in the trough, it is pressed down so as to make fairly good contact between the grains, no arcs are formed, but close observation shows that the main generation of heat occurs at the points of contact of the grains.

If an ammeter is included in the resistor circuit and the e. m. f. is kept constant throughout the experiment, it will be found that the current increases, showing a decrease in the resistance of the resistor, as the temperature rises, till finally a point is reached where the resistance becomes constant. If the trough is now covered with a piece of asbestos board, so as to diminish the radiation of heat from the resistor, the current will again gradually increase. For, by lessening the radiation of heat the temperature of the resistor is increased and the resistance diminished.

Instead of covering the resistor with a piece of asbestos board, let a weight be laid in it. The moment this is done the ammeter rises, indicating an immediate reduction in the resistance. This is caused by the reduced resistance of the points of contact of the grains of carbon.

To illustrate some of the characteristics of granular carbon resistors, the following experiment was made. In Fig. 3 the granular carbon resistor is shown in plan. W, W are the five brick walls of a trough, the ends of which are formed of the carbon terminals T, and T₂. The trough is divided into two parts by the carbon plate M. Granular coke that had been previously graphitized was then introduced into each half of the trough to a depth of 10 cms. The granular coke G₁ was composed of grains that passed through a screen having 5 meshes to the linear inch, and were held in a screen of 6 meshes to the inch. G₂ passed through a 3-mesh screen and was held in a 4-mesh screen. Good contact between the terminals and the granular coke was made by tightly packed graphite powder P₁ and P₂. Carbon rods A, B, C and D

were plunged in the granular carbon. Wires were attached to these rods so that they could be connected with a voltmeter and the voltage between A and B or C and D determined. Voltage between T₁ and T₂ was 110 volts. The current passing at any time was determined by an ammeter in series with the resistor.

After the current was thrown on, readings were taken at frequent intervals of the ammeter and the voltmeter connected up alternately with A-B and C-D. In a well-conducted experiment there should be two voltmeters used, so that the readings might be taken simultaneously; but, unfortunately, in the present instance only one voltmeter was available. The time between readings of the voltage between A and B, and C and D was about 30 seconds. After an interval of some minutes G₁ was covered with a piece of asbestos board, so as to diminish the radiation of heat from that part of the resistor. Later a weight of 3.5 kilograms was placed on G₁, then on G₂ and finally the same weights on both parts of the resistor. The area of a weight resting on the resistor was 67.5 square centimeters, thus giving a pressure of about 52 grams per square centimeter. The results obtained are given in the following table:

Time Mins.	Volts G ₁	Volts G ₂	Amperes	Remarks.
0	50.0	39.5	...	
2	46.5	37.0	70	
3	46.5	37.5	75	
4	46.0	37.0	85	
7.5	46.0	36.0	95	G ₁ bright red heat, G ₂ dull red heat
14	48.0	35.0	90	
16	48.0	34.5	90	
18.5	48.0	34.5	85	33 cms. of G ₁ covered with asbestos
20	47.5	36.0	85	
25	46.5	36.0	80	
29	46.0	37.0	80	
35	45.5	37.0	80	Asbestos taken off G ₁
39	45.5	37.0	80	
50	46.0	38.0	80	
52	34.0	45.0	105	Weight put on G ₁
53	40.0	42.0	100	Weight taken off G ₁
54	40.0	41.5	100	
55	46.0	28.0	120	Weight put on G ₂
56	43.5	34.0	112	Weight taken off G ₂
59	43.5	34.0	112	
60	42.0	30.0	135	Weights put on G ₁ and G ₂
63	44.0	30.0	138	
66	45.5	29.0	130	
68	45.0	32.0	100	Both weights taken off
88	46.0	32.0	100	

To facilitate the analysis of the results obtained from the experiment the curves in Figs. 4 and 5 have been drawn. The curve in Fig. 4 is drawn with minutes as abscissa and the

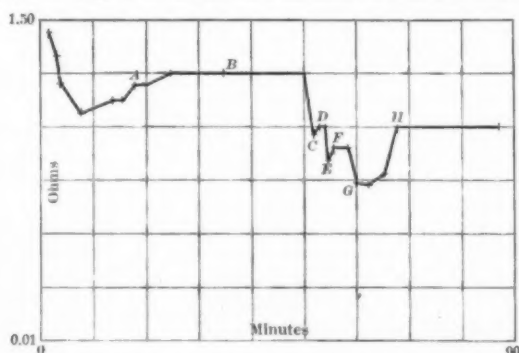


FIG. 4.—CHANGES IN RESISTANCE OF THE RESISTOR AS A WHOLE.

reciprocals of the current values as ordinates. Since the voltage at the terminals of the resistor was constant, the curve represents the changes in resistance of the resistor as a whole. The abscissæ of the curves in Fig. 5 are minutes, and the ordinates of the curves were obtained by taking the sum of the voltages between A and B, and C and D, and expressing them as percentages. The continuous line corresponds to G₁ and the broken line to G₂. These curves therefore serve to illustrate the relative resistances of G₁ and G₂ at any time

during the experiment. All the curves have been lettered in the same way: At A the asbestos board was put in G₁; at B the asbestos was taken off; at C the weight was put on G₁; at D the weight was taken off; at E the weight was put on G₂; at F the weight was taken off; at G weights were put on G₁ and G₂; at H the weights were taken off.

Consider first the curve in Fig. 4. As might be expected, the resistance decreases rapidly at first, since the resistivity of carbon decreases with increase of temperature. But at the end of 7½ minutes there is an increase of the resistance in spite of continued increase in the temperature of the resistor. As in the case of the resistance curve of the graphite furnace and the resistivity curve of the carbon rod, the most probable explanation of this increase in resistance is that the temperature of the points of contact of the carbon grains is sufficiently high to form carbides at the points of contact, and consequently to increase the resistance of the resistor. This explanation is

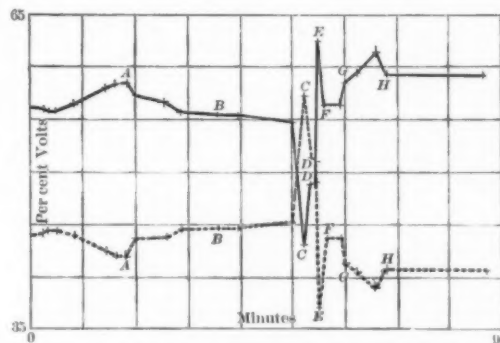


FIG. 5.—CHANGE OF RELATIVE RESISTANCES OF G₁ AND G₂.

confirmed by the observation that when using impure carbon grains in the resistor this phenomenon is much more marked than with pure carbon. In working a carborundum furnace with a resistor in the shape of a core of ordinary granular coke, the phenomenon is very distinct, the resistance first diminishing rapidly, then increasing, and finally diminishing again. On the other hand, if the core is composed of granular coke, which has been used in a previous run, and is therefore relatively pure, the phenomenon is much less distinct. The effect of putting the asbestos board over the resistor seems to be slight, the resistance apparently becoming constant. This result, however, is due to lack of sensitiveness in the ammeter. Other experiments of a similar kind have clearly shown that if the radiation of heat from a resistor is diminished there is marked decrease in resistance. The effect will be evident when the curves in Fig. 5 are examined.

A considerable decrease in resistance is obtained when the weight is put on G₁ at C, followed by an increase of resistance at D, when the weight is removed. But it will be observed that placing the weight on G₁ has permanently lowered the resistance. A similar result is obtained when the weight is put on G₂.

Finally, the resistance decreases at G when weights are placed on both sections of the resistor. But shortly afterward the resistance begins to increase rapidly, the reason for this probably being the same as before, viz., the formation of carbides at the points of contact of the grains. At this stage of the experiment the resistor was becoming very hot, and the formation of carbides would therefore be rapid. Here it may be noted that when the experiment was over and the resistor had cooled, it was found that a large number of the grains of carbon were coated with a greenish substance which evidently was amorphous silicon carbide. This was very clear in the case of the grains composing G₁, which was at a much higher temperature than G₂.

Turning, now, to the curves in Fig. 5, it is observed that G₁, composed of the smaller grains of carbon, has a greater re-

sistance than G₂. It follows therefore that the generation of heat in G₁ is more rapid than in G₂, and this causing a more rapid increase in temperature, the resistance of G₁ diminishes more rapidly than G₂. At the end of 4 minutes, however, this condition is reversed, the resistance of G₁ increasing as compared with G₂, although the resistance of the resistor, as a whole, is still diminishing, as may be seen by referring to Fig. 4. But the generation of heat being much more rapid in G₁ than in G₂, the temperature of the former is now much higher and probably the formation of carbides has begun. In the table of observations it is noted at the end of 7½ minutes that G₁ is at a bright red heat, while G₂ is merely dull red. The observation refers to the exposed surface of the two sections of the resistor, the interior of each being much hotter.

The increase of resistance of G₁, as compared with G₂, continues till A, when the asbestos is placed over the former. It should be noted that the asbestos board did not come in contact with the resistor, but rested on the bricks, so that its only effect was to diminish the radiation of heat from G₁. The result is a marked reduction in the resistance of G₁, as compared with G₂, although the resistance of the resistor as a whole was still increasing as is shown by Fig. 4. Here the increase in temperature has apparently more influence on the resistance than the formation of carbides. The removal of the asbestos at B does not show any appreciable effect. If the experiment is tried with a long resistor of granular carbon the effect of increasing or diminishing the radiation of heat is to cause distinct increase and decrease in the resistance.

When the weight is placed on G₁ at C the diminution in resistance was so great that G₂ then had a greater resistance than G₁. Even after removing the weight from G₁, the resistance of G₂ was still slightly the greater. When the weight is placed on G₂ at E, G₁ again shows the higher resistance, and when the weight is removed at F the difference in the resistances is greater than before the weights were applied to either G₁ or G₂. It appears from this that the application of pressure to G₂ produces a greater effect on the resistance than applying the same pressure to G₁. This is confirmed at G, where pressure is applied to both G₁ and G₂, for the difference in resistance is further increased.

The weights were left on G₁ and G₂ for 8 minutes, and the curves show that during that time the difference of the resistances increased rapidly. This was probably due in part to the more rapid formation of carbides in G₁ than in G₂, and in part to the more rapid increase of the temperature of G₂. Although on account of its greater resistance there was more energy developing in G₁ than in G₂, the temperature of the former was now so much the higher that the heat radiation was much greater and, consequently, the rate of increase in temperature was less than in G₂.

The conclusions to be drawn from this experiment may be summarized as follows:

1. When the current is started there is first a rapid decrease in the resistance of the resistor, followed by a slow increase. Although the present experiment does not show it, this increase is followed by a decrease if the conditions are such that radiation of heat from the resistor is prevented and its temperature continues to rise.
2. Other things equal, preventing the radiation of heat from a carbon resistor cause a decrease in its resistance.
3. If pressure is applied to the resistor the resistance decreases, and after removing the pressure the resistance is lower than it was before applying pressure.
4. Of two granular carbon resistors, each composed of grains of uniform size, the coarser grained resistor has the lower resistivity.
5. If the same pressure is applied to a coarse grained and fine grained resistor the decrease in resistivity produced is greater in the former than in the latter. All of these conclusions are of importance in practical work where a granular carbon resistor is used. As was shown before, it is important

to have some means of regulating the applied e. m. f. in order to compensate for the change in resistance.

When a current is passed through a carbon resistor its temperature will rise until the heat conducted away by the surrounding materials or radiated into space is equal to the heat generated. If the e. m. f. applied to the resistor is constant, then the watts will vary in an inverse sense to the resistance, and since the resistance varies in an inverse sense to the temperature, it follows that the watts eventually developed in the resistor will depend upon the rate at which heat is carried off. This is an important deduction, for it will be seen that it is possible to have two resistors composed of granular carbon of the same sized grains; to make the dimensions of the resistors identical, to apply the same e. m. f. to each resistor, and yet when a constant state is reached, one of them will generate much more heat per second, that is, use more watts than the other, simply because at first the rapid escape of heat is prevented.

A practical illustration of this is furnished by an experience of the writer which at first proved somewhat puzzling. A carborundum furnace was built in the usual way, with a resistor of granular coke. When the current was thrown on and the maximum voltage applied, it was observed that the resistance was somewhat lower than usual, for the ammeter showed that the furnace was taking a greater current than was to be expected. Under normal conditions the resistance of the core of a carborundum furnace decreases till the full amount of power for which the furnace is designed is used, and after that the voltage is regulated to keep the power constant, until finally a nearly constant resistance is reached. But in this furnace the resistance of the core, after decreasing to a certain extent, became constant long before the full power was generating in the furnace, and although the current was kept on for several hours there was no further change in the resistance. Inspection of the furnace showed that steam was coming off freely from the mixture which was quite warm, although the mixture in an ordinary carborundum furnace does not become warm on the outside till a considerable time has elapsed.

The explanation of the failure of the furnace to work was found to be that in making up the mixture of sand, coke, sawdust and salt for the furnace, wet sand had been used. No correction for the water in the sand was made, consequently there was a large excess of carbon in the mixture. This, combined with the presence of the water and the salt, made the mixture a fairly good electrical conductor, so that when the current was thrown on a large part of it leaked through the mixture. As a result, although on starting the furnace at the maximum voltage, the current passing was greater than usual and consequently the rate of generation of heat was greater, yet the temperature of the furnace did not rise sufficiently to bring the resistance of the core down to the working point. For as fast as the heat was generated it was lost by radiation or absorbed by the water to form steam.

In working with small furnaces it will sometimes be found that the resistance of the resistor will not diminish sufficiently to take the proper current, and this is often due to excessive cooling by radiation or conduction.

The influence of pressure on a granular carbon resistor must always be kept in mind. Suppose, for example, that the resistor is long, and that because of the design of the furnace, there is more pressure on one part than another. Then the place at which the pressure is high will have a lower resistivity than that at which the pressure is low and the temperatures will therefore be different.

Moreover, if the resistor is so designed that it has considerable depth, the lower part will be under greater pressure than the upper part, and consequently the heat generated below will be greater than above.

Since the experiment shows that the application of pressure to a granular carbon resistor produces a permanent change in resistance, even after the pressure is removed, it follows that

in constructing a resistor care must be taken to avoid packing the carbon down tightly in one place, and leaving it loose in another. Neglect of this precaution is a frequent cause of trouble.

The fact that a resistor composed of coarse grains of carbon has a lower resistance than one composed of fine grains, permits the adjustment of the resistance of the resistor to suit conditions as to the dimensions of the furnace and the available e. m. f. Starting with a resistor of solid carbon and proceeding by gradations to a fine granular material it is possible to obtain a great range of resistance.

While the effect of pressure, as shown by the experiment, is more marked when the resistor is coarse grained than when it is fine grained, this only applies to a limited extent. For carbon powder can be made an excellent conductor by judicious packing, and its use in this way is important. For example, in making contact between the granular carbon of a resistor and the terminals, finely powdered carbon, tightly rammed into place, is found to be very satisfactory. Graphite powder is, of course, much superior to amorphous carbon for this purpose, and probably the best material of all is found in the beautiful soft graphite obtained by the decomposition of silicon carbide.

Some of the considerations noted above only apply strictly to resistors composed of grains of carbon uniform in size. If a resistor is composed of carbon grains of a definite uniform size, it will have a certain resistance; but if the spaces between the grains are filled with finer grains of carbon, it is obvious that the resistance will be considerably diminished. In general it is better to use carbon grains of a uniform size in making a resistor, particularly if the construction is on a large scale, as the use of grains of different sizes make it difficult to obtain a uniform resistivity throughout the resistor.

Where resistors of greater resistivity than can be obtained from granular carbon are required it is necessary to mix with the carbon some other substance of high resistivity. The use of such a resistor is limited by the nature of the substance mixed with the carbon, since no other substance than carbon can withstand the highest attainable temperatures. The substance chosen should be very refractory, and for that reason a silico-carbide or silicon carbide seems at the present time to be most likely to give satisfactory results.

FLAME REGULATION IN CHEMICAL AND METALLURGICAL OPERATIONS.

BY CARLETON ELLIS.

So widespread has been the interest manifested in certain new methods of combustion and flame regulation, known collectively as the Eldred process, that at the request of the editor of this journal the writer will give in the following article a statement of the general principles upon which the new process depends.

The Eldred process is probably the first effort ever made in the attempt at the simultaneous regulation and control of the duration of combustion, and of the temperature and volume of flame. From a given amount of fuel the process provides for the generation of the heat in any space desired, either large or small, filling this space with heat at an even temperature throughout. The major portion of heat is not generated in the furnace or fire box, but in the heating chamber itself and throughout all parts of it at the same time. On another hand, the heat can be generated in a localized spot in any part of this space.

The heat can be generated at a relatively low temperature if necessary, this being controlled by the regulation of the duration of combustion. A flame can be made so cool that it will not ignite wood, and may pass through all stages of heat intensity from this degree up to a flame which will melt fire brick, and the change from low to high temperature can

be accomplished almost immediately at the will of the operator.

What we know about combustion has been almost wholly regulated by steam boiler practice. The prevalent idea of the conditions for satisfactory combustion is that the fuel must be burned in a pure air draft current with 50 to 100 per cent excess of air or oxygen. Such an excess of oxygen has been considered necessary for effecting complete combustion. A greater excess than this causes loss of heat energy by the sensible heat carried away in the escaping gases. Of course, the purer the air the better has it been regarded as a means for supporting combustion.

The ideas embodied in the inventions constituting the Eldred process are quite at variance with those above mentioned. The most radical departure involves the hypothesis that atmospheric air contains too high a percentage of oxygen for the economical combustion of fuel in many cases. As nature has not provided an atmosphere properly suited for combustion, it becomes necessary to create artificial atmospheres better adapted not only to maintain combustion, but to conduct it in such a way that the heat is applied at the point where it is most needed.

Previous to the advent of the Eldred process some attempt had been made to use coal in various arts, where low tem-

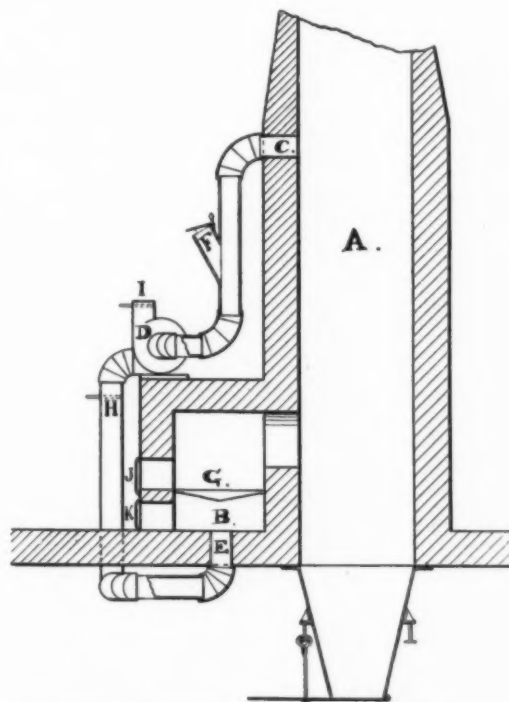


FIG. 1.—CONSTRUCTION OF APPARATUS

perature flame was required, by extending the area of combustion and diminishing its intensity, but all of these practices with which the writer is acquainted have failed of their purpose, and while repeated attempts were made to use coal either alone or in combination with wood, they have been nearly all unsuccessful, and have failed entirely to accomplish the application of heat of low intensity in an economical way.

One of these methods was to employ a steam as a diluent, but steam has a very high heat constant, by reason of which it is able to absorb and carry away a considerable amount of energy as sensible and latent heat, and, inasmuch as fuel must be burned to produce steam, this did not generally prove practicable nor economical.

Another very common method in certain arts has been to open the ash-pit doors wide and flood the fire with cold air.

This, of course, is very extravagant of coal, because a large part of the heat, instead of being utilized in the kiln or furnace, is carried out by the air forced through the fire, so that while the fire burns out very rapidly indeed, the heat of the kiln is not high and much more coal is burned than is necessary; the efficiency of the process thus conducted being so low as to make it extremely wasteful.

For these purposes the inventor, Mr. Byron E. Eldred, substituted a mixture of atmospheric air and a neutral gaseous "diluent" as described in U. S. Patent 692,257 of February 4, 1902. The first installation of this process was made on some lime kilns at a plant near Philadelphia, and showed a very decided saving over old methods. Since that time most of the lime manufacturers in the country within reach of cheap coal have adopted the process and the economy in its use has been determined beyond a doubt.

The type of apparatus used is shown in Fig. 1, as applied to a lime kiln of the conventional type, G being a furnace communicating with a cupola A through an opening or arch. J and K are the fire and ash-pit openings, provided with suitable doors. A draft pipe or conduit connects at its upper end with A, through opening C, and at its lower end with the ash-pit B, through opening E, and has interposed in it a fan-blower D. That part of the conduit above the fan constitutes the suction pipe of said fan, and the part below the fan constitutes a delivery pipe therefor. A gate or valve H controls this delivery pipe. The fan has also an auxiliary outlet or delivery pipe I, controlled by a gate or valve through which a portion of the kiln gases may be disposed of without causing them to pass through the fire. At F the suction pipe is provided with an air inlet, also controlled by a valve. By adjusting this valve, the relative proportion of air and kiln-gases in the draft may be exactly controlled.

The Eldred process, so far as investigated by the writer, seems to involve regulation of the composition and of the speed or volume per unit time, of the draft current of a furnace for the purpose of controlling the duration, temperature and volume of flame or of combustion. In its most characteristic application it involves the use of an artificially accelerated draft current, composed of air and a neutral gaseous diluent so proportioned as to retard combustion in the fuel bed and sufficiently accelerated to ensure a rapid and abundant evolution of combustible gases which, with suitable speed and dilution of the draft, may be developed into a long flame of large volume.

The diluent for the air consists of permanent gases which are neutral in so much as they are neither combustible nor supporters of combustion. In practice the waste gases of the process are always found to be sufficiently poor in oxygen to answer the purpose, and a portion of these is brought back from the stack and thoroughly mixed with such amount of fresh air as will produce the required percentage of oxygen in the mixture.

The process permits of wide regulation to attain desired results of various kinds under varying condition, and admits of many modifications, but in its most characteristic development the regulation is such that a flaming current of combustible gases and diluted air is carried to a distance before combustion is completed.

With a draft properly regulated for this purpose the furnace and fuel bed are cooler than with a pure air draft, and the body of diluent gases acts as an absorber and carrier of the heat of combustion which distributes this heat uniformly and lowers the temperature of combustion, but the more important action is that the liberation of the heat units of the fuel is greatly retarded and takes place at or near the material to be heated. In other words, the heat of the fuel is evolved at a point where it is needed, and where it can do direct work to the best advantage.

The amount and velocity of the draft current are closely interdependent factors with composition of the draft current

and must be carefully regulated. This regulation therefore should be with a view to best practice of the process and not to saving of heat units of the waste gases. The amount of the diluent draft current and its velocity through the fuel bed should be such as to force the inflated current of slow-burning combustible and diluent gases onward to the regions and material to be heated before they are burned out. On the other hand, economical practice of the process requires that they be given opportunity to burn out before reaching the return conduit. In order that the gases may burn out, the regions traversed by them should be such as not to chill them before there has been time to effect a complete union of the diffused combustible elements and oxygen, for otherwise much carbon monoxide will pass into the stack and will be largely wasted as the gases recovered and brought back to the fire are only a small fraction of the whole.

For the reason just stated the process is especially useful in arts, like lime burning, where the gases travel for a long

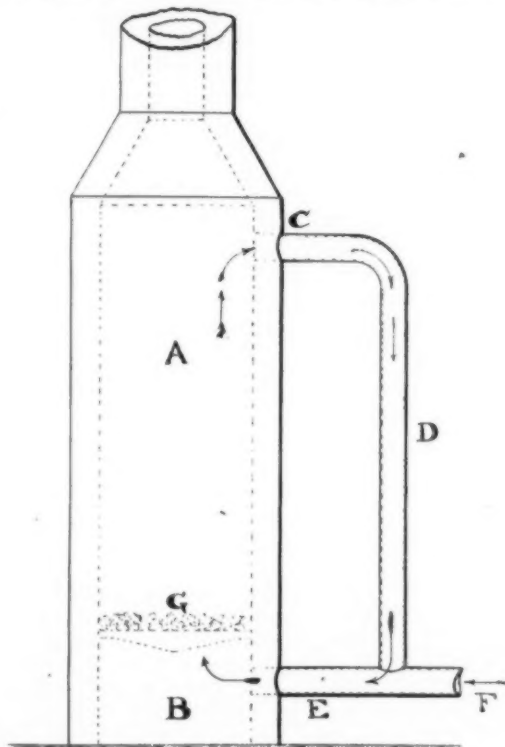


FIG. 2—GAS CYCLE.

distance in the highly heated rock, and are thus kept for a comparatively long time at a high temperature favorable to complete combustion.

In a lime kiln, or in any furnace where the gases can pass unchilled, they carry the heat in potential form and evolve the heat where it is needed. The advantage of such a process over those where the heating is accomplished partly by convection, but mostly by conduction, is obvious. The process is very flexible, and by proper adjustment the flame may be varied from the localized intense heat of the ordinary forced draft of pure air to the long, slow, more characteristic flame of the Eldred process, which, in an extreme case, may be made so cool as not to ignite wood.

The Eldred process involves a cyclic return of a portion of the waste gases, and this has led to numerous inquiries as to just what effect such a cycle of travel has upon the constitution of the escaping gases. To illustrate the questions involved in the so-called "gas cycle," reference is made to Fig. 2. In this diagram A represents a chamber filled with the material to be heated. A determined portion of the products

of combustion are drawn out at C and are carried back through C, D, E to ashpit B. A measured amount of air is admitted at F. The gas and air mingle and pass through the grate and fire box G. At the start the burned gases coming from the carbon fuel and passing up the stack normally contain nitrogen 79 per cent, oxygen 15 per cent and carbon dioxide 6 per cent. Suppose a portion of these "normal" gases to be drawn back at C and to mix with an equal amount of air from F, then the gas entering at E will contain oxygen 18 per cent and carbon dioxide 3 per cent, the nitrogen, of course, remaining substantially unchanged. These pass through the fuel and, it is assumed, burn the same amount of carbon as represented by that in the "normal" gas, or the equivalent of 6 per cent carbon dioxide.

The following table shows the progressive changes in the character of the entering and escaping gas. The nitrogen remains practically constant, namely, at 79 per cent, so it need not enter into the calculations.

Interval of Time.	Gas Discharged at Top of Kiln		Gas-Air Mixture Entering at E	
	Oxygen.	Carbon Dioxide.	Oxygen.	Carbon Dioxide.
0.....	per cent. 15	per cent. 6	per cent.	per cent.
1.....	12	9	18	3
2.....	10.5	10.5	16.5	4.5
3.....	9.75	11.25	15.75	5.25
4.....	9.375	11.625	15.375	5.625
5.....	9.1875	11.8125	15.1875	5.8125
6.....	9.0938	11.9062	15.0938	5.9062

The limiting values therefore are

9	12	15	6
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Or, in other words, the application of such a cyclic process, starting with stack gases carrying 6 per cent of carbon dioxide and continuously diluting these with an equal volume of air (calculated at the same temperature), would cause the percentage of carbon dioxide in the stack gases to increase to 12 per cent, or double its normal amount, and the oxygen would be reduced to 9 per cent, or the excess air expressed in percentage of that chemically combined would be reduced from about 250 per cent to approximately 75 per cent excess, a difference of 175 per cent. In many furnaces 80 per cent of the heat generated is carried away in escaping gases. Could such a case as above described be carried out in practice, the reduction in the excess air by 175 per cent would be equivalent to an increase in fuel efficiency of about 40 per cent. The variable nature of the fire, among other things, in practice does not, of course, permit of an adjustment so effective that the above conditions can be realized. Besides, the Eldred process uses to advantage a smaller fraction of the stack gases than that above mentioned.

According to the theory of limits, equilibrium in this system is never attained, but actually it is quickly reached so far as can be shown by analysis of the gases at different points.

In calculating the gas-air mixture required per pound of coal, one has to take into consideration two factors. First, that less oxygen by volume is present than in ordinary air, and, secondly, that less excess oxygen actually is required with the Eldred process. A slow drawn-out combustion seems to require less excess oxygen for its completion than a rapid combustion.

The following formula serves for calculations. The cubic feet of gas-air mixture A required per pound of coal allowing no excess is:

$$A = \frac{32(T + 440)}{5\theta}$$

where T is the temperature and θ the oxygen content of the gas-air mixture entering the furnace.

By suitable regulation of the draft in accordance with the above principles and by subsequent treatment, the resulting gas current or flame may be adapted to a wide variety of uses without loss of any of its characteristic advantages and economies. A large number of these uses have been tried and are now in successful practical operation. The results have shown unexpected special advantages in almost every case.

It is in successful operation on billet-heating and annealing furnaces, on lime, cement and brick kilns, on ore-roasting, reverberatory furnaces, etc. It may be used in puddling mills, rolling mills, in ceramic work and in many other arts. A recent ingenious modification of the process makes it applicable to steam boilers, to which it has been heretofore unsuited.

RESULTS OBTAINED WITH THE ELDRD PROCESS.

Lime Burning.—As applied to lime burning in the ordinary way, a ton of coal will burn only about the same amount of lime as a cord of wood, although the former has more than twice the heat energy of the latter. With the Eldred process the full heat value of the coal is obtained and a ton of coal will produce from 2 to 2½ times the amount of lime that is now produced from a cord of wood. On dolomite rock as high an average output as 200 barrels per day of lime has been obtained from a single kiln. One firm reports a saving of \$50 per week per kiln by the use of the process.

The Eldred process gives as high an efficiency as 5¼ pounds of lime per pound of coal burned. This means that more than 85 per cent of the coal is used in the actual calcination of the lime stone, while less than 15 per cent is lost in the sensible heat of the escaping gases and through radiation.

The output of a kiln may be increased at least 50 per cent over that of any other known method, by the application of the Eldred process in conjunction with induced draft. The latter, by itself, will not give satisfactory results, as the fire becomes intensely hot and overburns the lime. By the use of diluent gases the fire will be tempered to the proper calcination point, and the flame increased enormously in volume, with the result that the output of the kiln shows a gain of more than 50 per cent. The Eldred process gives a lime product of great uniformity. This is because the nature of the flame is such that there is no danger from overburning the lime. That is to say, the heat never need reach the point where the silica usually found in lime stone fuses with the lime to form vitreous silicate of lime. Such a vitrefaction cannot be avoided in the ordinary coal fire, and the result of this overburning often proves disastrous, as the silicious particles so produced do not slake out immediately like quick lime, but only after the elapse of several months. When they do slake, the plaster or mortar is fractured and the walls of a building are thereby given a most unsightly appearance. The Eldred process overcomes this heat localizing tendency of the ordinary coal fire, and gives rise to a long flame of low heat intensity which brings about the uniform calcination of lime in a most efficient and economical manner.

The diluent gases retard combustion on the grate and carry the generation of the heat into the body of the stone. Knowing these facts an engineer would predict a long life for the furnace and grates. Such is the case. The method reduces repair bills to an exceedingly low figure. In the saving on repairs alone a kiln will in one year's time fully pay the cost of the installation.

Iron and Steel Industry.—Regulated and adapted to the conditions of heating furnaces used in rolling mills, the process gives a very mellow heat. The iron or steel is easily worked and the product is of unusually good quality, and there is a saving of about 25 per cent in fuel as well.

The annealing of iron is perfectly done with a fuel saving of 20 to 30 per cent. The iron is especially well annealed under this process, owing to the long, even flame of uniform

temperature which surrounds the annealing cases or boxes. The flame has less oxidizing action upon the latter than does the ordinary fire. It is quite out of question to use steam for regulating the fire temperature, owing to the resulting oxidizing action. The use of an inert gas overcome this difficulty.

Cement.—Cement burning is another wide field to which the Eldred process has been adapted and in which it has been found to be of value, as tests recently made demonstrate that on rotary kilns the coal is reduced from 20 to 40 pounds per barrel of cement produced. The high temperature required in the clinkering zone is easily obtained. In fact, with the Eldred process the writer obtained a temperature of 3150° F. in a cement kiln, as registered by a Wanner Optical Pyrometer; 2700° F. is the highest temperature actually needed.

Brick Burning.—In the burning of brick we have conditions somewhat similar to those obtaining in a lime kiln. A voluminous flame of uniform temperature is desired. A high temperature such as would result from using a forced draft of pure air overburns the brick adjacent to the fire box, causing a considerable loss from "rejects." The use of a diluent gas overcomes this difficulty. This, together with a better application of the heat has resulted in a saving of over 50 per cent in the cost of burning brick. In one instance which was brought to the writer's attention, the time of burning was reduced from 17 to 11 days, and the product was of much better quality than that ever before manufactured at the plant in question.

Metallurgy.—In metallurgical work and ore-roasting remarkable results have been obtained. Ore roasted with this process is more easily leached, so that a more thorough extraction is obtainable. On account of the even flame and low temperature, continually maintained, the sulphur of the ore is more thoroughly oxidized, and there is less fusion and formation of slag difficult to leach. The saving in fuel on the average amounts to 40 per cent, and it has never, to the writer's knowledge, fallen below 25 per cent, and, if to this item is added the saving from better extraction and from reduction in labor, the economy reaches a very high total.

Correspondence.

THE LIMITS OF PHYSICAL SCIENCE.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY.

Sir—I accept the opportunity offered to discuss further the topics considered in the editorial "On the Reality of Atoms and Ions," which appeared in the November number of this journal.

With much that is said in that editorial, and especially with the quotation from Maxwell, I am in hearty accord. The es-

sential difference between the author of the editorial and myself appears to be that I believe we may attain and, indeed, have attained positive knowledge with regard to some matters which lie beyond the limits of sense-perception, while he, apparently, has no such belief. In using the term "positive knowledge," I mean that we may obtain knowledge which differs in *degree*, but not essentially in kind from our knowledge of physical laws and of physical facts. From the standpoint of philosophy we have no positive knowledge of anything outside of ourselves. Everything which comes to us through sense-perception requires more or less of interpretation before it can become a valuable part of our mental property, and such interpretation is always liable to error. It is only because our successive interpretations are consistent with each other and with the interpretations of others that we acquire a conviction of the existence of a universe external to ourselves, which is well-ordered and uniformly consistent with itself.

Some chemists and physicists appear to think that there is an essential difference in *kind* between knowledge of physical laws and the knowledge which we gain by inductive processes, as, for instance, our knowledge of atoms, and that the former knowledge is positive, while the latter is not. That physical laws are like the atomic theory in being only an interpretation, and that the two do not differ in their essential nature, but that they differ chiefly in the complexity of the concepts involved will, I think, be clear from an illustration.

At the close of the nineteenth century it was universally accepted as a law of nature that one element could not be transformed into another. Facts recently discovered have raised very grave doubts of the universality of this law. It is evident that the law is only an interpretation of the facts which were known, and that it is subject to a revision, which is similar to the revision and amplification which the concept of atoms has undergone at the hands of chemists and physicists for the past one hundred years. Our interpretation may correspond very imperfectly with the reality, but that there is some approach to the truth I firmly believe.

A sentence in Mendeleeff's "A Chemical Conception of the Ether," a translation of which has just appeared, is so apposite that I cannot refrain from quoting it. He says: "Although skeptical indifference is prone to discern only a 'working hypothesis' in the conception of ether, yet the earnest investigator, seeking the reality of truth, and not the image of fantasy, is forced to ask himself what is the chemical nature of the ether." I am quite willing to put myself beside Mendeleeff as one of those who "seeks the reality of truth," while I am fully aware that the search is a long one, and that the goal is to be reached only through countless years, during which we can see only imperfect truth.

WILLIAM A. NOYES.

Bureau of Standards, Washington, D. C.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY AND ELECTROMETALLURGY.

Production of Ozone by Silent Discharges.—In view of the increasing interest which the production of ozone from atmospheric air attracts at present for the industrial purposes of sterilizing water and bleaching, an article by A. W. GRAY, published in the *Physical Review* of November, should be of interest. Though his investigation was mainly undertaken to test Warburg's theory of the Siemens & Halske ozonizer and to improve the construction of the latter, yet some results ob-

tained by him are of more general interest. As ordinarily constructed, the effective part of a Siemens ozonizer consists of two coaxial cylindrical shells of glass separated by a layer of the gas to be submitted to the action of the electric discharge—the whole forming a compound condenser of three layers. The author modified the construction as shown in Fig. 1. The effective portion that comes between the electrodes is of large diameter, with thin walls as close together as possible, and short enough to permit a flow of gas sufficiently rapid to

prevent the concentration of ozone from becoming so great that the deozone action of the electric discharge pointed out by Warburg would have an appreciable effect. The remainder of the generator is of thicker glass. Interior insulation is secured by extending the gas space above, and by reducing the diameter there; and the flow of gas is facilitated by increasing the distance between the walls in the upper portion as well as by providing a considerable space at the bottom. That the insulation thus obtained was effective, even when considerable water-vapor was present in the oxygen, seems

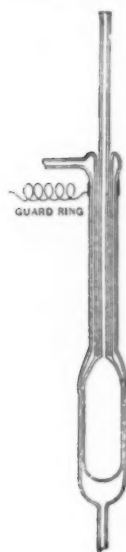


FIG. 1.—OZONIZER.

clearly indicated by the results obtained by the author. External surface insulation is increased by carrying the conductor to the inner electrode down through a narrow glass tube sealed in the neck as indicated. As an additional precaution a metallic guard ring connected to earth surrounded the neck of the generator just below the gas exit. The electrodes were of silver, deposited on the glass in order to avoid strains which would be caused by the employment of a liquid.

An interesting result found by the author is that the mass of ozone produced per coulomb sent through the gas increases with the potential difference applied between the electrodes of the generator, and that the increase in the former is apparently directly proportional to the increase in the latter. A number of experiments were made to determine the effect of considerable water vapor on the production of ozone. It was always found that under such circumstances the yield of ozone per coulomb sent through the gas was from ten to fifteen per cent less than when well dried oxygen was employed with the same potential difference between the electrodes of the generator. And here, too, there seemed to be indications that, as long as the gas remained under the same conditions, the increase in the yield of ozone was directly proportional to the increase in the potential. The results which the author draws from his investigation with respect to the production of ozone for technical purposes are summed up by him as follows:

First, good surface insulation of the generator, both internal and external, by means of such device as described above (Fig. 1).

Second, dry oxygen.

Third, charging and discharging as sudden as possible. For this reason the resistance and self-induction of the circuit should be reduced to a minimum, and it is also possible that operation by connection with a Leyden battery might yield better results than the ordinary method of employing an induction coil or an alternating-current dynamo, as these machines could not give such a rapid change in the potential difference between the electrodes. Merely placing the generator in parallel with the spark-gap of an electrical machine, as was done by Shenstone and Priest, is inefficient, because the charging takes place so slowly that no illumination, and consequently no ozone, is produced.

The Electric Furnace in the Zinc Industry.—The October issue of *L'Electrochimie* contains a rather long paper by SALGUES on the treatment of zinc ores in the electric furnace. He describes three different applications. The first is for making zinc powder. In this case all the zinc minerals, whatever their nature, are mixed with coal as reducing agent, and charged into the electric furnace; the zinc vapors are then greatly diluted by CO gas, and only zinc powder is obtained. The second application is for making solid zinc. This may be done by three means. (a) The zinc is distilled in form of concentrated vapors; this necessitates two furnaces; in the

first the zinc is reduced at a sufficiently low temperature; in the second—the electric furnace—the zinc is distilled. (b) Only the electric furnace is employed, but the operation is carried out at a temperature sufficiently low to prevent the distillation of the zinc; it is obtained in liquid form below the slag; of course, a resistance furnace is to be used in this case. (c) "The third process involves a partly electrolytic principle. The minerals are first preliminarily reduced at a low temperature, but without being mixed with carbon; the reduction is accomplished exclusively by means of carbon monoxide. This means that the zinc silicate remains unchanged, since it can be reduced by solid carbon only. After this reduction the minerals are charged into the furnace. The fusion zone is regulated for the production of a very fusible slag, in view of the operation at low temperature. The electrical heat is produced simply by the Joulean effect. The fusion of the zinc, obtained from the preliminary reduction of the oxide is accomplished in the same way as in case (b); the metal collects below the slag. The zinc silicate is electrolyzed. For this reason the furnace is operated, not with alternating, but with direct current, in such a way that the zinc is obtained in the same way as aluminium. Very little zinc powder is obtained." The author gives some notes on the construction of the furnace, and of the condenser for getting powdered zinc; he also points out the advantages which the electric furnace has in zinc metallurgy. He finally deals with the production of zinc white.

Nickel.—A summary of the development of electrolytic processes for the production of nickel is given by J. HESS in the *Zeit. f. Elektrochemie*, October 14, mainly on the basis of articles published in **ELECTROCHEMICAL INDUSTRY**. The summary contains nothing that is new to our readers, with the exception of the following remark, which should prove interesting. "The Browne process shows that the electrolytic separation of nickel and copper from chloride solutions was possible and successful without getting chlorine as an end product. This justifies the expectation that a well-developed method using sulphate solutions should also be successful. We may, perhaps be later in a position of reporting on such a process by Schuckert & Co."

Electrometallurgy.—In a continuation of J. IZART's serial in *L'Industrie Electrique*, August 25, nickel and lead are dealt with. The author considers very briefly the methods of separating nickel and copper from nickel-copper matte, and refers to the refining of nickel in order to recover the precious metals contained in commercial nickel. He then deals with the Salom process of reducing lead, and the Betts process of refining lead.

Electric Glass Furnaces.—In the *Elektrochem. Zeit.* of October, J. BROWN begins to give an illustrated summary of the various electric furnaces patented for glass manufacture. In 1881 Reich & Co. (German patent 17,736) devised a method of smelting glass electrically on a small experimental scale. Askenasy (German patent 917,328, 1896) let the electric arc play over the surface of bricks and pottery ware to produce a glazed surface. Becker, a German glass manufacturer, became interested in the use of electric smelting in 1897, and took out several German patents (101,176, 138,416). The first experiments were made with Becker's furnace in Cologne in 1900. Luehne took out two English patents in 1899 (23,090 and 24,148). Several modifications of the Becker process were patented by Voelker (German patents 134,935, 124,702, 128,250, 131,291). The article is illustrated by diagrams, taken from the patent specifications, and is to be continued.

Plating Sheet Zinc with Nickel.—In the *Journal de l'Electrolyse* of October 15, M. BRANDELY makes some remarks on the plating of sheet zinc with nickel and the use of nickelled sheet-zinc as a substitute for sheet iron plated with tin for certain purposes. The zinc is coated only on one side with

nickel. He insists especially on the careful cleaning and preliminary preparation of the surfaces before they are plated. The zinc surface is first very carefully polished, freed from grease and washed, and then coated with copper, either on one or on both sides and then again washed. This is followed by the process of plating with nickel. The composition of the solution preferred by the author is double sulphate of nickel and ammonium 600 grams, sulphate of ammonium 100 grams, boracic acid 250 grams, and 10 liters of distilled water. The current density is 1.2 amperes per square centimeter of surface to be nickeled. The plates are then washed and polished.

Nitric Acid from Air.—In the *Elektrochemische Zeit.*, of October, O. KAUSCH gives an illustrated summary of the various processes which have been proposed for the fixation of atmospheric nitrogen by means of electric discharges. Besides the experiments of Cavendish and Lepel the following processes are described on the basis of patent specifications: Naville and Guye, Prim, Siemens & Halske, McDougall, Bradley and Lovejoy, Birkeland and Eyde, Kowalski.

THEORETICAL AND EXPERIMENTAL.

Temperature Measurements up to 1600° C.—A. L. DAY and E. T. ALLEN have recently prepared in the laboratory of the United States Geological Survey, apparatus for generating, regulating and measuring temperatures up to 1600° C., which has proved easy of manipulation and uncommonly exact. It is, in effect, a reproduction of the Reichsanstalt high temperature scale. The temperatures were measured with thermoelements exclusively. The authors obtained from Heraeus, Hanau, Germany, a set of four elements cut successively from the same roll of wire, which, when joined together, proved to be identically alike in their readings over the range of temperature covered by the gas scale of the Reichsanstalt (250° to 1150° C.), within the limits of observation error. They were taken to the Reichsanstalt and measured in the original melting-point furnace with the same elements in terms of which the gas-thermometer scale has been expressed, and five careful comparisons were made. These were the melting points of cadmium, zinc, antimony, silver and copper. The elements were then taken by messenger to Washington and further compared in an electric furnace, which will be described below, and the melting points of the same group of metals again determined. The metals used, however, were from other sources than those which had served for the calibration at the Reichsanstalt. When the test was finished, the authors were enabled to assure themselves that, although all the constants in the measuring apparatus—thermoelements, resistances, standard cells, metals, etc.—had been changed in the transfer from the Reichsanstalt to the Geological Survey at Washington, the aggregate error nowhere exceeded 1° over the entire range from 250° to 1150°. It will be remembered that 1° was the accuracy which the standard gas thermometer showed at 1000°. The thermoelectrical system of the authors is, therefore, now doubly established—(1) by direct comparison and (2) through an independent series of metal melting points—upon the gas thermometer scale of the Reichsanstalt within the limits of error of the latter, and can be verified at any time with the help of two of the elements which have been laid aside for this purpose, or by means of the melting points of the metals. The scale is therefore permanent. The four metals which were used in Washington for fixing points of the temperature scale were cadmium, zinc, silver and copper. The cadmium and zinc were taken from the regular listed chemicals of Eimer & Amend (zinc, "C. P. in sticks; cadmium, metal sticks"), the silver was the well-known test silver of the Philadelphia Mint Laboratory, while the copper was also from Eimer & Amend ("C. P. copper drops cooled in hydrogen"). The melting points, as determined by the authors are as follows, the figures given in parenthesis representing the corresponding temperatures de-

termined in the Reichsanstalt. Cadmium 321.7 (321.7), Zinc 420.0 (419.0), silver 962.2 (961.5), copper in air 1065.3 (1064.9), copper in reducing atmosphere 1083.6 (1084.1).

Four more elements were later prepared and calibrated in the same way. Of these, two are of the usual form (Fig. 2), and two are of a new design (Fig. 3), which has proved very effective in the determination of the melting points of non-metallic substances. It will be seen from the diagram of the insulated element that the hot junction is protected from the melting charge by a casing of platinum-iridium (0.1 mm. thick) and by a protecting tube of refractory Berlin (Marquardt) porcelain (1.5 mm. thick). Very early in the experiments upon the mineral silicates the authors became aware that the conductivity of these minerals for heat would be much poorer than in similar charges of metal. Furthermore, the charge of mineral which the furnaces could carry was only one-fourth to one-third as great as the metal charges used in the calibrations because of the great difference in specific gravity and the limited space which could be heated to a fairly uniform temperature. For these reasons the changes of state would be less sharply marked upon the heating and



Fig. 2.



Fig. 3.

THERMO-ELEMENTS

cooling curves than melting points, and it was feared that the readings of the protected element might prove too high or too low through inability to take on the temperature of the surrounding mass promptly. To obviate this possible source of error, the form of thermo-element indicated in Fig. 3 was devised. It really amounts to nothing more than the ordinary form of platinum-platin-rhodium element with the platinum wire insulated from the other by a very slender porcelain (Marquardt) tube and the platinum-rhodium wire broadened out and wrapped around this tube like a cap over the portion which dips into the charge. The hot junction is then the lower extremity of the cap where the platinum wire emerges from its insulating tube and is welded inside the platinum-rhodium cap.

The furnace, in plan, differed but little from that in use for melting-point determinations at Reichsanstalt. In the working out, two important changes were introduced, in order to enable it to reach the higher temperatures of the mineral melting points. A more refractory and better insulating material was substituted for fire-clay in the hotter parts and the coil was wound on the inside of the oven tube instead of outside. A diagram of the furnace in section is shown in Fig. 4. It could be used for any temperature up to 1600° C. without any difficulty or especial precautions, and could be regulated to maintain a constant temperature at any particular point for long periods of time. The coil, which was obtained from Heraeus, was of platinum-iridium wire (90 parts Pt, 10 parts Ir), 1.5 mm. in diameter, and required about 3000 watts to maintain a constant temperature of 1600° C. The furnace was car-

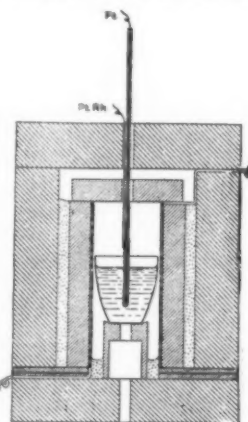


FIG. 4.—ELECTRIC FURNACE.

ried at times on a 110-volt direct-current street main, but accurately constant temperatures could not be depended upon without a storage battery.

Electrolysis of Acid Solutions of Aniline.—When hydrochloric acid is electrolyzed, chlorine is set free at the anode, and, as L. GILCHRIST remarks in a paper in *Jour. of Phys. Chem.*, November, it seemed quite feasible to dissolve a little aniline in the acid and let it be converted into chlor-aniline by the chlorine set free, just as the soda in the electrolysis of salt solutions is converted into hypochlorite. When he made this experiment, however, aniline black—one of the oxidation products of aniline—was formed. The reason is that the liberation of chlorine requires 1.25 volts, while the formation of aniline black from 0.1 n aniline in solutions of n-hydrochloric acid or n-sulphuric acid takes place at 0.95 volt (small anode, hydrogen cathode). Therefore, only traces of chlor-aniline are formed. On the other hand, since the oxidation potential of aniline (0.95 volt) lies above the decomposition voltage of hydrobromic acid (0.75 volt in 4n — HBr), on electrolysis of a solution of aniline in hydrobromic acid bromine is liberated and aniline black is not formed, but brom-anilines. The oxidation potential of m-nitraniline in sulphuric acid solution (1.43 volts) is much higher than that of aniline.

Deposition of Aluminium from Ethyl Bromide Solution.—The full account of H. E. PATTEN's investigation of this subject, which was noticed in our October issue, page 413, is to be found in the November number of the *Jour. of Phys. Chem.*

Electrolysis of Potassium Acetate.—With respect to the paper of Foerster and Piguet, abstracted in our November issue, page 459, some critical remarks are made by H. HOFER and M. MOEST in the *Zeit. f. Elektrochemie*, October 21. The former authors are said to have overlooked the formation of methyl alcohol in the electrolyte.

Passive State of Metals.—An article by O. SACKUR on the anodic solution of metals and the passive state is found in the *Zeit. f. Elektrochemie*, October 28. The author makes some remarks on the passive state of zinc and states that it can be explained neither by Faraday's oxide film theory nor by the valence theories of Finkelstein and Mueller. His own views are essentially as follows. Between a bivalent metal and any aqueous solution an equilibrium is quickly established according to the equation $M + 2H^+ \rightleftharpoons Me^{++} + H_2$. With metals which do not decompose water—and only these can become passive—the discharged hydrogen cannot be developed as gas, since it has not atmospheric pressure or the required overvoltage. The solution of the metals, to form ions, can therefore continue only to the equilibrium concentration, if the discharged hydrogen is not continually removed. This takes place quickly, for instance, by reaction with Cl ions, if they are present. But the combination with anodically discharged oxygen may be very slow. The speed of this reaction depends on the catalytic action of the metal. The author, therefore, concludes that the capability of metals to become passive must be the greater the smaller their catalytic action on the combination of hydrogen and oxygen. He considers this view as a useful working hypothesis.

Influence of Inert Ions on the Electrolytic Formation of Periodates.—In the electrolysis of neutral solutions of iodates with polished platinum anodes, the quantity of periodate formed is in general very small, but can be largely increased by the addition of indifferent ions. A paper on this subject is contributed to *Zeit. f. Elektrochemie*, September 23, by E. MUELLER. We have two means for increasing the ampere-hour efficiency of the electrolytic oxidation of iodic acid—which, if there are no additions, is never more than 1 per cent with a polished platinum anode. One means is to use platinum as anode and to add a fluorine ion to the electrolyte (for instance, in the form of potassium fluoride). The other means is to use pure iodic acid without any addition, and to substitute a lead peroxide plate for the platinum anode. Both

means increase the oxidation, but the addition of the lead peroxide acts by decreasing the "reaction resistance," while the action of the fluorine ion is due to an increase of the anodic potential. One may say that the fluorine ion increases the "anodic overvoltage" of the platinum. This shows that the overvoltage depends on the nature of the electrolyte.

Preparation of Persulphates.—A similar beneficial effect of the presence of fluorine ions has also been observed by E. MUELLER in the electrolytic preparation of persulphates. His experiments are described in the *Zeit. f. Elektrochemie*, September 30.

Preparation of Chlorates.—With respect to a German patent of Siemens & Halske on the beneficial effect of fluorine ions on the electrolytic production of chlorates, F. FOERSTER and E. MUELLER show in the *Zeit. f. Elektrochemie*, September 30, that this effect is absolutely different from that described in the preceding two abstracts. In general, slight acidulation of a chloride solution causes secondary formation of chlorate, decreases the attainable content of hypochlorite and the anodic development of oxygen and increases the output of chlorate. What Siemens & Halske do is simply to acidulate the sodium chloride solution by addition of hydrofluoric acid.

The Influence of the Cathodic Material on Reduction.—The important part which the nature of the cathode material plays in the electrolytic reduction in general and especially in the reduction of aromatic nitro-compounds, is well known. The effect produced depends on the cathode potential, and a certain reduction energy corresponds to a given cathode potential (Haber). In this connection a paper by W. LOEB and J. SCHMITT, published in the *Zeit. f. Elektrochemie*, September 23, is of interest, dealing with the influence of the cathode material upon reduction of m- and p- nitrotoluene. The reduction is smallest for nickel cathodes and increases for cathodes of the following materials in the order mentioned: Zinc, copper, copper together with copper powder.

Freezing Point of Highly Saturated Salt Solutions.—With reference to a recent investigation of H. C. Jones and F. H. Getman, a note is published in the November issue of the *Journal Phys. Chem.* by L. C. DE COPPET on work done by him, as early as 1871 and 1872, on the molecular depression of the freezing point of water, produced by some very concentrated salt solutions. For some salts the molecular depression of the freezing point reaches a minimum with increasing concentration to increase again afterwards, while other salts exhibit a continuous decrease in the molecular depression as the concentration increases. More than thirty years ago he showed that the continuous decrease may be explained in two ways; first, by the dissociation of hydrates formed by the solute at the expense of the solvent; second, by dissociation of the solute, probably hydrolytic dissociation.

Action of Amalgams upon Solutions.—In the controversy between G. Fernekes and G. McP. Smith (pages 67 and 201 of this volume), Fernekes again takes the floor in the November issue of the *Jour. of Phys. Chem.* He denies that the electrolytic dissociation theory can be harmonized with the facts under discussion, while he thinks they may be simply explained on the basis of Kahlenberg's views.

Very Small Ionic Concentration.—F. Haber's paper on this subject, abstracted in our August issue, page 320, has brought about an interesting discussion in the columns of the *Zeit. f. Elektrochemie*, as was to be expected. The issue of August 12 contained three papers by G. BODLAENDER, R. ABEGG and H. DANNEEL who propose several hypotheses to defend the reality of the extremely small ionic concentrations in question. F. HABER replies in the issue of September 30.

MISCELLANEOUS.

Tin-Lead Alloys.—L. Peetz gives in *Metallurgie* for June 22 and 29, the results of extensive researches which he has made for the purpose of discovering a means of producing

pure tin from these alloys. He directed his search towards finding a flux which would take up the lead and leave the tin. This he found to be partially, but not completely, accomplished by melting in the alloy, and agitating with it, a double chloride of tin and potassium. While the lead attacks this flux, yet there was always some left in the tin, and there was always loss of tin chloride by volatilization, so much as to make the method commercially impracticable. We think it quite likely that an electrolytic method of refining could be easily devised for this alloy, the problem being to find an electrolyte which does not attack as anode material either one of the two metals, and dissolves the other. However, another commercial principle intervenes, at least in this country, which is that there is such a large use for lead-tin alloys as solders that thousands of tons of pure lead and tin are melted together annually to make them, and there is really no need or use for a commercial process for separating them.

Study of Alloys.—E. S. SHEPHERD, in the *Iron and Steel Magazine* for September, calls attention to some neglected details in the experimental study of alloys. His criticism, which is perfectly just, is that several recent papers on this subject have lost much of their value, because the work did not include all the secondary changes which can be noted by the pyrometer, when studying cooling curves, but was limited simply to giving the freezing-points. The other points of arrest, marking the separating out of eutectic mixtures, or changes of molecular structure, occurring below the freezing point, are of primary importance in connection with the microscopic study of these alloys, and where these have not been included in the observations, the work will have to be done over. Another criticism is the lack of proper stirring, while determining freezing points, rendering possible errors of 40° or 50° because of surfusion. The densities of the alloys are also data of considerable importance, and easily determined, yet most investigators neglect the assistance which may thus be obtained. The article closes with the regret that more determinations of the specific heats and heats of formation of alloys are not being made.

Soldering Aluminium.—This question, which is of great importance for the application of aluminium for various purposes is discussed by MILLET in *L'Electrochimie*, October (from *La Métallurgie*, April 13). He gives two compositions of a solder. The first has a melting point sufficiently high to stand the heat necessary for "mercury gilding;" it consists of 30 parts Al, 13Ag, 6 Cu, 45 Cd, 3Sn, 3Zn. It is made as follows: First an alloy of 20 parts Al, 13Ag, 6 Cu is made in a crucible and cast into ingots. This alloy is added to a second alloy, while in fusion and consisting of 10 parts Al and 30Cd. To the mixture is added the balance of 15Cd, 3Sn, 3Zn. The melting of the second alloy and the mixture of the two alloys has to take place at a temperature not above dull red. A second solder, for ordinary purposes not requiring high temperatures (since its melting point is at 300° C.) consists essentially of equal parts of zinc and cadmium, and is made as follows. The zinc is melted in a crucible and the cadmium is added. To this alloy is added a 50 per cent copper-aluminium alloy in various proportions, according to the resistance desired; the maximum amount of the Cu-Al alloy is 5 parts per 95 parts of the Zn-Cd alloy. No flux is required with either solder.

IRON AND STEEL INSTITUTE PAPERS.

The recent international meeting of the Iron and Steel Institute brought to our doors some of the best-known metallurgists of the world, and we are certain that they have returned to their homes with very vivid recollections of American hospitality. At the two meetings for reading of papers, held at the Hotel Astor, New York, on October 26 (a few days too late to be reported in our issue of November 1), there were read several interesting and valuable papers. The following abstracts are made from advance copies of the papers.

C. V. BELLAMY, director of public works at Lagos, gave a long account of "A West African Smelting House," with photographs and most unique details of this primitive method of reducing iron ore. Some analyses of the ore, slags and products, made by F. W. Harbord, show the operation to be a direct process, the metal being reduced by charcoal and subsequently partly decarburized in the same furnace by means of fusible oxides, which largely dephosphorize the metal. The character of the community, their enthusiasm for, and pride in their work, and particularly their contempt for the inferior European iron, make interesting and amusing reading.

A. McWILLIAM and W. H. HATFIELD presented a paper on "Acid Open-Hearth Manipulation," in which the general results of Brinell on the action of manganese, silicon and aluminium in producing sound ingots were confirmed, *i. e.*, that silicon is relatively 5.6 times as efficient as manganese, percentum for percentum, in increasing the soundness of ingots, and aluminium 28 times. Besides this, details were given showing that the rate at which silicon is oxidized and removed from a bath of steel depends as much on the character of the slag on the bath as on the intensity of the oxidizing influences; that by making a slag suddenly highly siliceous the silicon, which before that was falling, afterwards commenced to increase, although the furnace had been cooled off somewhat by the siliceous additions. The conclusion to be drawn from these results is that a fifty-ton bath of steel covered by slag and heated by white-hot gases, is no exception to, but only a complex example of, the laws of chemical equilibrium; that a suitable slag which, so to say, invites silica is a predisposing attraction which helps to determine the oxidation of silicon; that a slag high in silica tends rather to give up silicon to the combined attraction of carbon and iron; and, in short, that the chemical action which will occur in any given case is governed by the relative masses of the reacting substances in juxtaposition, and the laws of chemical equilibrium. That it may be known where the responsibility lies, it is fair to state that the conclusions above formulated are those of the reviewer, and are not taken from the paper in question.

EMILE DEMENGE, in a paper upon "The Utilization of Exhaust Steam from Engines Acting Intermittently, by means of Regenerative Steam Accumulators and of Low-Pressure Turbines on the Reteau System," brought up a matter which, in spite of its inordinately complex title, is of general interest to all users of power. The idea of the system is to utilize the large quantities of low-pressure steam which at present escapes to waste from such devourers of steam as the reversing engines in rolling mills, large steam hammers, and other machines acting intermittently, and of such a nature that multiple expansion, etc., to provide economy in the use of steam, is inapplicable. Under these conditions, Mr. Reteau proposes to discharge this intermittent supply of exhaust steam into regenerative steam accumulators, which, by their size, serve as reservoirs for the intermittent supply, furnishing themselves a constant supply of steam at an equalized low pressure, to the steam turbines. The accumulator has heavy trays of cast iron within it, which absorb the latent heat of vaporization of any steam coming in above the average pressure in the accumulator, and give out that heat in converting water into steam, if the steam pressure in the accumulator tends to fall. The accumulator thus serves as a reservoir of heat and an equalizer of pressures, and furnishes a steady supply of low-pressure steam, although receiving intermittent supplies of relatively high-pressure exhaust steam. In what is called a "compound accumulator," water is contained in tubes, and thus increases the thermal capacity of the accumulator as a "heat fly-wheel." With the steam turbines it is found that they furnish excellent results at low pressures, in fact, efficiencies of 65 to 75 per cent of the power theoretically obtainable, when expanding from atmospheric pressure to that of the condenser, while piston engines would yield only 35 to 40 per cent. In fact, the turbines work most economically on low pressures, and piston engines

on high pressures, so that the two supplement each other exactly.

HENRY HUSE CAMPBELL, of Steelton, Pa., general manager of the Pennsylvania Steel Co., and author of his well-known treatise on the manufacture of structural steel, discussed the much debated question of the influence of carbon, phosphorus, manganese and sulphur on the strength of open-hearth steel. The formulæ formerly worked out so carefully by the speaker, whereby the strength of acid steel is 38,600 pounds, increased 1210 pounds for each 0.01 per cent of carbon and 890 pounds for each 0.01 per cent of phosphorus, and for basic steel 37,430 pounds increased 950, 1050 and 85 pounds for each 0.01 per cent of carbon, phosphorus and manganese present respectively (Campbell's "Manufacture and Properties of Iron and Steel," pages 482-528), have been found of the utmost practical importance, having been applied to every heat of steel made at the speakers works for the last ten years, with differences usually much less than 1,500 pounds between the calculated and actually-obtained strengths, and seldom attaining 2500 pounds. To check the formulæ, a new investigation was made, including data from nearly 700 heats of acid steel and 110 heats of basic steel. Three bars were pulled from each heat on two different machines, and chemical analyses were made by different methods, that for carbon by three schemes.

The revised formulæ differ from the previous ones mainly in assigning a variable value to the influence of manganese, whose effect is now found to vary with the amount of carbon present. For acid steel the formula for the ultimate strength, in pounds per square inch, is $40,000 + 1000$ times each 0.01 per cent carbon, plus 1,000 times each 0.01 per cent phosphorus, plus a value for manganese varying from 160 to 9600 pounds, according as the carbon lies between 0.10 and 0.60 per cent, and the manganese 0.40 to 0.60 per cent. For basic steel the corresponding values are 41,500 pounds to start with, increased 770 pounds for each 0.01 per cent of carbon, 1000 pounds for each 0.01 per cent of phosphorus, and from 550 to 7500 pounds for the manganese, depending on its amount and the carbon content. Tables are given for the manganese correction, for different values of carbon and manganese. It appears to the reviewer, that the manganese correction might have been expressed numerically as a function of the carbon and manganese, and then the carbon function merged into the carbon factor, leaving the manganese with a single factor, and so simplifying the formulæ. However, as they stand, the research and its results are of a monumental character, creditable alike to the American metallurgist who made them, and to the firm whose liberality and far-sightedness made the work possible, and of value to the whole metallurgical world.

A committee of analysts, JÜPTNER, of Austria, BLAIR in the United States, DILLNER, in Sweden, and STEAD, of England, reported on a "Comparison of Methods for the Determination of Carbon and Phosphorus in Steel." The net result of the investigation showed satisfactory concordance as regards the determinations of carbon, but relatively large variations in the phosphorus. Expressing the latter in thousandths of one per cent, the amounts found in one sample varied from 78 to 102, a tremendous variation, considering that the analyses were

made under test conditions. If the variations were possibly due to variations in the samples, then the whole investigation loses its value; if due to errors in the analyses, then the latter certainly need an increase in precision.

J. M. GLEDHILL discussed "The Development and Use of High-Speed Tool Steel," and exhibited a splendid collection of samples for the works of Whitworth and Co. The paper was a triumphant exposition of the revolution in machining which the high-speed tool has effected, and the statement is made that these steels have not been obtained "without exhaustive scientific research." As constituents of these steels, it is found that the greatest efficiency is obtained with carbon 0.4 to 0.9 per cent, chromium 1 to 6 per cent, tungsten 9 to 16 per cent, silicon not over 3 per cent, molybdenum not yet determined. One of the best Whitworth rapid steels contains 0.55 per cent carbon, 3.5 chromium and 13.5 tungsten. In the discussion, the fact was developed that hundreds of tons of ferro-molybdenum have been used in making American high-speed steels, from 3 up to 10 per cent being used. The electrometallurgist must feel a particular interest in these steels, and share in some degree in the satisfaction which their use is giving, when he sees that the particular ingredients which give the steels their value are mainly electric furnace products, and the general use of these steels binds tighter the bonds between the electrochemist and the greatest modern metallurgical industry. An electrical method of heat and hardening the tools, described by Mr. Gledhill, consisted in using the tool as cathode in a miniature Burton water-pail forge, the heating and quenching temperatures being thus under perfect control.

Probably the most important paper presented at the meeting was by JAMES GAYLEY, the well-known blast-furnace manager, and vice-president of the United States Steel Corporation on "The Application of Dry-Air Blast to the Manufacture of Iron." Enough has been written on the theory of this subject for a generation, but Mr. Gayley directed the expenditure of several thousand dollars in actually trying the matter at the Isabella furnace of the Carnegie Steel Co., and was able to present to the world for the first time a record of results actually accomplished. The blast was dried by being drawn through a chamber artificially cooled by a liquid ammonia refrigerating system; and 90 per cent of its moisture was thus frozen out. The refrigerating machinery consumed 535 hp. The blowing engines were slowed down from 110 to 89 revolutions per minute, to correspond with the coldness of the air drawn in, and the power thus saved was greater than the expenditure for the cooling plant. The average amount of coke used in the furnace per ton of pig iron made was cut down from 2147 pounds to 1726 pounds, a decrease of 20 per cent, while the output of the furnace per day increased from 358 to 447 tons, a gain of 25 per cent. Besides these enormous advantages, the furnace with dried blast worked more uniformly, being practically unaffected by sudden variations in the weather, and producing a regular output of uniform composition, whereas furnaces alongside, with ordinary blast, showed sharp irregularities. The net results are such that it may be predicted that the dried blast will become a regular part of the equipment of all modern blast furnaces.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Electric Furnace.—Henri Harmet, St. Etienne, France. Patent 772,354. October 18, 1904. Application filed March 20, 1902.

The furnace, which is intended to serve for the direct con-

version of iron ores into iron or steel, is shown in cross-section in Fig. 1. This section is taken at right angles to the one given in ELECTROCHEMICAL INDUSTRY, vol. I., page 422, and shows the upper part of the apparatus more in detail. The four steps of the conversion, namely, the calcination, the reduction,

the fusion of the reduced metal, and the refining are carried out in three vessels, only two of which are shown in the figure. The ore is introduced into the calciner *d*, mixed with the necessary fluxes, but without addition of coke. The shape of the calciner in its upper part is that of an inverted cone. The lower part is contracted for a certain distance, and then widens out considerably. This peculiar shape is stated to secure the proper

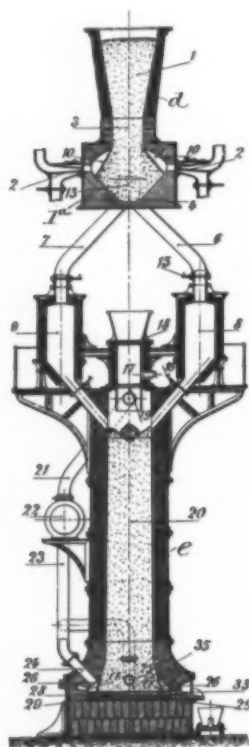


FIG. 1.—IRON REDUCTION FURNACE.

a heating vessel 17 of refractory material, into which a portion of the hot gas from the top of the reducer is introduced. The hot ore, flux and coke then travel downwards in the reducer *e* and are reduced in their passage by the carbon of the charge, aided by a portion of the gases collecting at the top of the reducer, which are rich in carbon monoxide. A suitable quantity of them is drawn off through pipe 21 by an exhaust fan 22 and blown at high pressure through pipe 23 and tuyeres 24 and 25 into the fusion zone of the apparatus, a little above the level of the slag. This procedure is stated to be very important, in order to be sure that the ore is completely reduced before the zone of fusion is reached. The reduced charge is then melted in the crucible 25, by means of a series of electrodes, not shown in the figure, which are arranged at equidistant points around the circumference of the crucible 25, and are preferably introduced through the top wall of the crucible, so as to be as nearly vertical as possible. The electrodes only dip into the slag 28, the electric heating being done entirely by resistance, and as they should constantly dip into the slag, the variations in the height of the latter must be very small. They should also be only a small distance away from the base of the crucible, and the latter is therefore constructed bell-shaped, with a very flat arch *a*. The increasing diameter of the crucible is necessitated by the requirement of accommodating a sufficiently large number of electrodes to transmit the heavy currents used in the operation. The slag is drawn off through a Lürmann tap and the metal goes into a refining vessel. The latter

ranged on the inside of the kiln wall, which flue conducts the consists essentially of a chamber of circular-horizontal cross-section, and provided with a charging door and tapping holes for the slag and metal respectively. It is not movable, in order to keep the bath as quiet as possible, and to prevent it from mixing with the slag. It is heated by carbon electrodes, which pass either through the top or the walls. The subject of the economic reduction of iron and steel directly from the ore is one which admits of much discussion and has been thoroughly ventilated in the pages of *ELECTROCHEMICAL INDUSTRY*. Whether the above apparatus might be a commercial success, is hard to decide; there is that much in its favor, that the inventor, Mr. Harmet, is a practical metallurgist of long experience and presumably well acquainted with the manufacture of iron and steel.

Electric Furnace.—C. P. Steinmetz, Schenectady, N. Y., assignor to General Electric Company. Patent 773,821, November 1, 1904. Application filed May 24, 1900.

The furnace is intended for the production of temperatures ranging between those ordinarily obtained by combustion, and that of the electric arc. Its action depends upon the fact that many refractory materials, such as refractory oxides, silicates, tungstates, chromates, etc., while showing a high resistance at ordinary temperature, become conducting when heated, the conductivity increasing with the temperature. The furnace illustrated in the specification is of simple construction, and consists of a block of refractory material having the above characteristics. It is hollowed out so as to form a receptacle for the substance to be acted upon. The terminals for conducting the current into the furnace are cone-shaped pieces of carbon, which are inserted into openings provided in the refractory material at opposite ends of the furnace, and project somewhat into the central cavity. The refractory material between the electrodes has to be heated up, of course, before a current can flow, and while external heat may be applied to the furnace for this purpose, it is preferred to do it by means of a small rod or filament of carbon arranged between the terminals and embedded within a recess in the bottom of the central cavity. The temperature is regulated by varying the electromotive force impressed upon the furnace by any suitable means, such as division of the primary of a transformer, the secondary of which is connected to the furnace. Owing to the potential gradient or drop in voltage along the heated space being of the magnitude of 1000 volts per inch, as compared to, say, 10 volts per inch in the carbide furnace, it is possible to expend a large amount of energy in a comparatively small space, and thus to produce extremely high temperatures, and to accomplish the desired chemical reactions. Mr. Steinmetz states that he has found by experiment that by heating aluminium silicate by this means, it fuses to a transparent mass, colored yellowish by impurities and of the nature, hardness and composition of topaz. He has also succeeded by small traces of chromic oxide and cobaltic oxide in obtaining green and blue transparent masses of the nature of emerald and sapphire, and in other cases he produced a red color.

Electric Kiln.—F. E. Dickinson, Kendallville, Ind. Patent 773,853, November 1, 1904. Application filed January 12, 1903.

The object in the construction of this furnace has been to overcome the heat losses in kilns such as used for the manufacture of brick, pottery, etc., by reason of the intake of cold air required to maintain combustion and the injurious effect upon the wares, such as pottery, etc., by the admission of cold air into the treating chamber. The kiln consists essentially of a round masonry construction with arched dome. Around its lower part are distributed at equal distances a series of rectangular, radial heating chambers, tightly closed and roofed over. One or more pairs of carbons are introduced air-tight through openings in the opposite side walls of the heating chambers and the arcs are struck between them. Each of the heat chambers opens into an upright flue ar-

air heated by the arcs to the roof of the kiln, whence it descends on the articles to be heated. A perforated false bottom is provided in the kiln, which communicates with a series of passages by which the partially cooled air is reconducted into the treating chambers in close proximity to the arcs, to be heated again and to re-enter into circulation as described above. A central opening in the dome permits the escape of moisture given off in the beginning of the operation of the green wares and permits a limited ventilation whenever desired. It is claimed that on account of the continuous circulation of the heated air only a slight reheating is required to compensate for the loss of heat by radiation from the walls of the kiln, and an economy in fuel and labor is effected.

ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

Manufacture of Cellulose.—Carl Kellner, Vienna, Austria.

Patent 773,941, November 1, 1904. Application filed March 18, 1903.

The process aims at the utilization of the chlorine produced in the electrolysis of alkali or metallic chlorides. The portions of plants from which the cellulose is to be produced are first treated with water or preferably with milk of lime or a very weak solution of an alkaline carbonate or hydroxide. After the excess of liquid has been removed by suitable means, the portions of plants under treatment are subjected to the action of electrolytic chlorine, which causes the incrusting substances (lignines) to be oxidized and to be converted into substances completely soluble in very weak alkaline liquids, and in many cases completely soluble in hot water. Care has to be taken that the materials are promptly removed from the chlorinating vessel as soon as they are permeated by the chlorine, since otherwise the cellulose would be converted into oxycellulose and chlorinated in various stages, whereby the product would become very brittle and of very little value. After the chlorination the materials are treated with water, and if any portion of the chlorinated incrusting substances still remains insoluble in the water, they are treated with a very weak solution of milk of lime or caustic alkali or alkali carbonate. The residue, which consists of nearly pure cellulose, is well washed with water and bleached if desired, and is then dried and placed on the market. Mr. Kellner states that one hundred parts, by weight, of air dried pine-wood requires ten parts, by weight of lime, or 0.15 parts by weight of caustic soda, absorbs thirty-two parts by weight of chlorine, and requires for the second bath twenty parts by weight of lime, or 0.30 parts by weight of caustic soda, loses in the first bath 0.4 parts by weight of its weight and produces fifty parts by weight of cellulose. One hundred parts by weight of esparto requires twenty parts by weight of lime, or 1.5 parts by weight of caustic soda, absorbs 15 parts by weight of chlorine, and requires for the second bath twenty parts by weight of lime or three parts by weight of caustic soda, loses in the first bath 1.2 parts by weight of its weight, and produces fifty-five parts by weight of cellulose. As only a small amount of alkali hydroxide or carbonate is required for the treatment of the cellulose containing substances, it is obvious that the larger portion of the alkali produced in the electrolysis of the alkali chloride can be removed as such and placed on the market, while the entire amount of the chlorine is utilized to a better advantage than in the production of bleaching powder.

Electrolytic Apparatus.—A. Brichaux, Brussels, Belgium, Assignor to the Solvay Process Co., Syracuse. Patent 774,230, November 8, 1904. Application filed October 4, 1898.

The apparatus, illustrated in cross-section in Fig. 2, is evidently intended for the electrolysis of alkali chloride, with a mercury cathode. It comprises a receptacle A for the electrolyte, with a mercury cathode a^2 on the bottom and a series of conductors a^3 as anodes. The principal object in the construction has been to provide for the establishment and the

maintenance in the electrolyte of two layers of unequal density, a heavier one a , and a lighter one a' . The formation of these layers is brought about by means of the partitions B, B', B'', which may be fixed, but are generally movable up and down, and may be adjusted by means of the nuts $b b'$. The vessels C C' contain the material to be electrolyzed, and are generally of unequal size. The heavier electrolyte enters into the

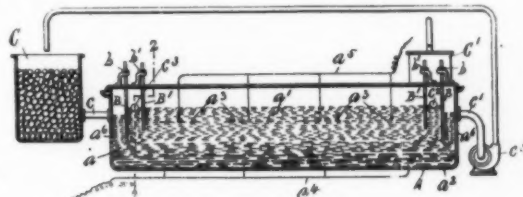


FIG. 2.—ELECTROLYSIS OF ALKALI CHLORIDE.

receptacle A by means of pipe c , from vessel C, and at the opposite end of the apparatus is removed through pipe c' into a pump or suction device c'' , whence it returns to the vessel C, thus keeping up the circulation. The lighter layer of liquid a' circulates in a similar manner by means of pipes c^2 and c^3 and vessel C'. In the operation of the apparatus the lower layer of liquid is almost or entirely saturated with the material to be electrolyzed, *f. i.*, alkali chloride, while the upper layer contains a lesser amount. It is claimed that the dense lower layer serves the purpose of a diaphragm without the inconveniences attendant upon the use of a solid diaphragm. It is stated to remain practically free from the substances, such as chlorine, which are liberated at the anode, inasmuch as it is saturated with the material to be electrolyzed, such as alkali chloride, and that as it is maintained in circulation as a distinct layer it does not perceptibly mix with the upper layer of lesser density. No provision is shown for discharging the amalgam, in order to liberate the sodium which it takes up during electrolysis, and presumably this operation takes place in a separate vessel, after which the mercury is again returned to the electrolyzing vessel.

STORAGE BATTERIES.

Storage Battery.—C. B. Morgan, Cleveland. Patent 773,961, November 1, 1904. Application filed April 18, 1904.

The invention aims at providing a light portable battery, especially for automobiles. For this purpose the inventor provides a plate furnished on the inside with a series of pockets formed by vertical and cross-ribs, two of such plates being soldered together. The plate is cast of aluminium and then electroplated with nickel or other relatively cheap conducting metal which is not attacked by the electrolyte. The pockets are then filled with aluminium cubes, balls, squares, granules or other pieces, which are also electroplated. With these pieces such active material is incorporated as is needed to completely fill the interstices. The outer surface of the plate is provided with numerous fine perforations for the purpose of circulation.

Process of Electrolytically Producing Lead Peroxide Layers Upon Positive Accumulator Plates.—J. Diamant, Raab, Austria-Hungary. Patent 774,049, November 1, 1904. Application filed January 4, 1904.

The process relates to the acceleration of the formation of layers of peroxide of lead upon the surface of the battery plates. For this purpose there is added to the electrolyte a sulphonic or oxysulphonic acid derivative of methane, and of its hydroxyl substitution products, such as methylsulphonic acid, methylene disulphonic acid, methylenedisulphonic acid, oxymethylenesulphonic acid and oxymethylenedisulphonic acid. The derivatives of oxysulphonic acid are derivatives of the oxymethylene sulphonic acid, and of the oxymethylenedisulphonic acid, $\text{CH}_3(\text{OH})(\text{HSO}_3)$ and CH_3

(OH)(HSO₃)₂, respectively. Sulphonic acids of this kind are obtained usually as mixtures by the action of sulphuric acid or sulphuric anhydride or fuming sulphuric acid upon organic compounds having a methyl group, which is easily split off, for instance, methyl alcohol, methyl sulphuric acid, ethyl alcohol, acetaldehyde, acetic acid, or the like. The different sulphonic or oxysulphonic acids may either be separated from each other by taking advantage of the different solubilities of their salts, and added in a pure form to the electrolyte used for forming the plate or the mixture may be added as such. During the electrolytic process the above substances will furnish only sulphuric acid and carbonic acid, neutral in their action upon the formed accumulator plate.

Storage Battery.—E. A. Sperry, Cleveland. Patent 773,686, November 1, 1904. Application filed February 11, 1904.

The invention relates specifically to large batteries such as are used in central stations, and has for its object the diminution of the thickness of the walls of the containing vessels, and the doing away with the rigid connections which render it difficult and expensive to remove any electrode for inspection or renewal. The construction, as shown in Fig. 3,

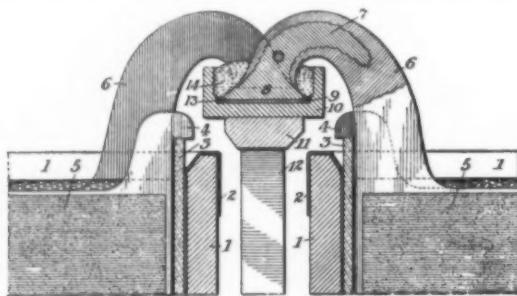


FIG. 3.—STORAGE BATTERY CONSTRUCTION.

comprises a containing vessel 1, with comparatively light walls and a lead lining 2. A vertical glass plate 3 at each end of the vessel serves as support for one end of the plates by means of the lug 4. The other end of the electrode has a terminal lug 6, which curves upwards over the end of the vessel and then downwards again. The lug has a flat face and rests directly on a copper plate 9, which is supported on the flat bottom of the trough 10. The shank 7 of a contact piece 8 of iron is cast into the lug 6, serving both to stiffen it and to increase its conductivity, and, moreover, making it possible to decrease the contact resistance between the contact piece and the copper plate by amalgamation. A layer 13 of mercury is placed in the trough 10 for this purpose, covering the contact surfaces. In order to exclude acid fumes, the rest of the trough is filled with plastic insulating material, preferably vaseline. The trough 10, of insulating material, such as vulcanized fiber or wood, rests on a wooden beam 11, which in turn is carried by posts 12. By this arrangement the walls of the containing vessel are relieved of one-half of the weight of the electrodes, thus making it possible to choose thinner and less expensive vessels, while the removal of any electrode can be readily effected.

Storage Battery Electrode and Process of Making Same.—E. A. Sperry, Cleveland. Patent 773,685. November 1, 1904. Application filed January 28, 1904.

The object of the invention is to produce a highly porous active material, preferably consisting of nearly equal parts of litharge and minium, and to provide the body or bodies of porous active material carried by the grid with relatively large feeder pores for the electrolyte. For this purpose a carbonate of lead is first chemically precipitated from a solution of a lead salt, which carbonate may be the normal carbonate PbCO₃ or any of the basic carbonates, but preferably the basic carbonate known as white lead. The carbonate may be

precipitated from an aqueous solution of any soluble lead salt, such as the acetate or nitrate, but it is preferably produced by electrolyzing an aqueous solution of sodium acetate, using a lead anode, and continuously introducing carbonic acid into the electrolyte. The pure precipitated lead carbonate, which is very finely divided, is then roasted to expel the carbonic acid, the roasting being by preference carried to such a point as to produce a porous mixture containing 10 parts of litharge and 12 parts of minium. The porous oxides may be directly applied to the battery grid or support, but it is preferred to add a salt which can be readily dissolved out by placing the electrode in water, also a salt which is capable of partially combining with and hardening lead oxides. Ammonium sulphate is preferably employed for this purpose, from 5 to 10 per cent being mixed with the material and the mixture then applied to the grid or support and pasted or press-welded into place. The electrode is then placed in water, by which the greater part of the ammonium sulphate is dissolved out, thus leaving large feeder pores for the electrolyte. The plate is then formed by any usual process.

GALVANIC ELEMENTS.

Electric Battery.—T. L. Roberts, New York. Patent 771,498, October 4, 1904. Application filed October 14, 1903.

The battery belongs to the type of dry cells, and consists of a containing jar of wood, which contains two wooden frames of suitable size, the sides of which are covered by sheets of cloth, and which are filled with a mass of conducting and depolarizing material. The latter is in the form of a paste of powdered carbon and manganese peroxide, moistened with a solution of zinc chloride. Carbon rods, serving as one electrode, pass through this paste. The positive electrode, a sheet of zinc covered on both sides with a liquid-absorbing medium, such as blotting paper or wood pulp, moistened with a solution of zinc chloride, is placed between the two frames. A little pan with water, into which the absorbent covering of the zinc dips, may be provided for the purpose of keeping the covering moist by capillary attraction. The air is allowed to permeate freely through the depolarizing mass and to restore to the latter the oxygen consumed during the action of the cell.

Battery Holder.—F. Jackson, Denver. Patent 772,415, October 18, 1904. Application filed March 4, 1904.

The invention is to be used in connection with dry batteries for producing sparks in gasoline or other vapor-operated connecting and disconnecting wires when replacing a spent battery with a fresh one, and at the same time to provide for securely holding the batteries in place. A mechanical construction embodying these points is described and illustrated in detail. It consists essentially of a box with a series of compartments, each of which is provided with a metal casing designed to partially enclose and tightly hold an ordinary dry battery. Conductors extend from the casing of one battery to the top of the adjoining compartment, and contact is made with the carbon tops of each cell by means of a contact plate, which is pressed against the carbon by a spring.

Medical Battery.—L. W. Pullen, Philadelphia. Patent 772,959, October 25, 1904. Application filed February 18, 1904.

The battery consists of a core of insulating material, such as wood, having lateral projections, one of which is longer than the other. The shorter one fits into a tube which also contains a galvanic cell, and suitable provision is made for connecting it with an induction apparatus which is located within the other longer end of the core. A tube is also fitted over the end which carries the induction coil, and provision is made for adjusting the tube longitudinally for the purpose of regulating the strength of the secondary current.

Clamp for Battery Electrodes.—E. G. Dodge, Orange, N. J. Patent 773,249, October 25, 1904. Application filed June 27, 1904.

The clamp is adapted for batteries of the type in which the

negative plate consists of molded copper oxide or other oxide, and provides for securely holding and locking them and preventing their accidental detachment.

Electric Battery.—C. F. Mackey, Philadelphia. Patent 773,331, October 25, 1904. Application filed December 11, 1903.

The inventor claims in an electric battery a zinc positive element forming a casing with a perforated wall, flanges at its upper end forming support hooks, a carbon negative element in the casing, a receptacle to which the casing is fitted, the flanges of said casing engaging the edge of the receptacle and an electrolyte in the receptacle.

MISCELLANEOUS.

Process of Electrically Treating Gases.—K. Birkeland, Christiania, Norway. Patent 772,862, October 18, 1904. Application filed June 15, 1903, divided and refiled April 2, 1904.

The process described in the specification is specially intended for the treatment of air for the purpose of producing nitrogen compounds from the atmospheric nitrogen. It has formed the basis of a paper read by Edstrom before the Electrochemical Section of the recent International Electrical Congress at St. Louis, an abstract of which is given in *ELECTROCHEMICAL INDUSTRY*, vol. II., page 399. In principle it is

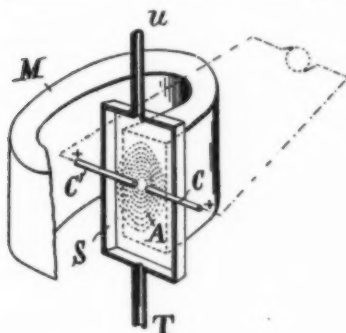


FIG. 4.—FIXATION OF ATMOSPHERIC NITROGEN

based upon the fact that electric arcs produced between electrodes situated within a magnetic field may be dispersed or spread out by the action of the magnets. An arc or high or low tension may thus be spread out into a disc or sheet having a volume several hundred times as large as the original arc. The main features of an apparatus working on the above principle are diagrammatically illustrated in the adjoining Fig. 4 in perspective view. In this figure M represents the electromagnet, one pole of which is broken away so as to afford a better view of the arrangement. The electrodes C C', between which the arc is struck, are enclosed in a housing S of fireproof material, the air inlet being at T and the outlet at U. With a suitable distance between the electrodes and a suitable current, as well as a suitable magnetism, there will be produced a dispersed arc, indicated by the curves a, which arc is in the shape of a permanent sheet or disc at right angles to the lines of force of the magnetic field. If currents of high voltage, *i. e.*, 5000 volts are used, it has been found suitable to place the electrodes at a fixed distance of some millimeters apart. The air coming in at T therefore passes through the flame in the direction of its plane, and is thus exposed to an energetic action of comparatively long duration. An alternative form of the apparatus shows a circular electromagnet between the poles of which is placed a tubular housing, which is divided into a series of vertical channels by means of partitions alternately extending to the top and the bottom plates.

A zig-zag channel is thus formed through which the air is passed. In each of the compartments thus formed a pair of electrodes is placed. It is claimed in the above-mentioned paper that with this process an efficiency of 900 kilograms of 100 per cent nitric acid per kilowatt-year as compared with published results of 700 kilograms per kilowatt-year, according to the Bradley and Lovejoy system, and 580 kilograms per kilowatt-year in the method employed by Kowalski and Moscicki has been obtained.

Process of Removing Water from Peat.—B. Kittler, Memel, Germany. Patent 772,891, October 18, 1904. Application filed March 19, 1904, divided and refiled June 17, 1904.

Apparatus for Removing Water from Peat.—B. Kittler, Memel, Germany. Patent 772,717, October 18, 1904. Application filed March 19, 1904.

The process depends upon the treatment of peat simultaneously by the action of heated gases, and an electric current, the process being further aided by the establishment of a partial vacuum in the treating chamber of the apparatus, thus providing an active circulation of the heated air. The apparatus consists of a cylindrical outer vessel, inside of which is arranged another cylinder with its walls parallel to the first one, but located so that an annular chamber is formed between it and the outer vessel. An insulating cover and bottom are provided. A central hollow shaft is arranged within the apparatus, which carries a series of helically arranged arms. The latter are also hollow, and each of them forms a sort of trough, covered with a strainer, through which the heated air passes into the inside of the apparatus. The shaft is rotated and is in connection with the positive pole of the source of current. The above mentioned inner cylindrical vessel, which is perforated in order to act as a strainer, is connected to the negative electrode. A charging pipe in the top, and a discharging pipe in the bottom of the apparatus are also provided. The operation of the apparatus consists in filling it with peat and setting the agitating arms into rotation. The hollow shaft is then connected with the supply of hot air, and the vacuum pump started. The hot air will then pass through the peat, while the electric current passes out at the agitator arms and travels towards the inner straining vessel. It is claimed that every particle of the peat is thus acted upon, while the partial vacuum will cause a constant discharge of water into the annular chamber mentioned above, whence it is removed by the pump. The helical arrangement of the agitator arms causes the peat to descend, so that a compact mass of dried peat accumulates on the bottom and is withdrawn through the discharge pipe at desired intervals.

Apparatus for the Electrical Treatment of Air.—J. E. Mitchell and D. Parks, St. Louis. Patent 773,407, October 25, 1904. Application filed July 9, 1904.

The apparatus comprises an air pump, and two upright air tubes. In the bottom of each of the latter there is provided a stationary electrode, while a movable electrode is introduced through the top. By means of suitable mechanism, shown in detail, these movable electrodes are alternately raised and lowered, and an arc is thus struck and extinguished between them and the stationary electrodes. The mechanism is so arranged and connected with the motion of the air pump, that the latter draws the air alternately through the two air tubes, and that simultaneously with the movement of the air through the tubes the electrodes are drawn apart, thus causing an electrical discharge and insuring that all the air drawn into the pump is subjected to the action of the discharge.

RECENT METALLURGICAL PATENTS.

IRON AND STEEL.

T. J. Tresidder (U. S. Patent 774,958, November 15) patents a steel containing iron and carbon, manganese, nickel and tungsten in about the following proportions: Carbon, 0.28 to

0.32 per cent; manganese, 0.25 to 0.30 per cent; nickel, 2.25 to 2.50 per cent; and tungsten, 0.28 to 0.32 per cent, the remainder being iron. Such steel, while readily perceptible of a fibrous structure under suitable treatment is claimed to

retain that fibrous structure under conditions that would ordinarily produce a crystalline structure, such, in particular, as the sudden chilling from a very high temperature necessary in the process of face-hardening after supercarburization.

M. P. Boss (774,304, November 8) patents a method for converting iron ore into steel continuously within a single furnace structure. The method consists essentially in subjecting the ore to the reducing action of a hydrocarbon flame and at the same time to the combining action of a hydrocarbon vapor. The process depends, therefore, "upon the observed fact that in a furnace heated by a hydrocarbon fuel a hydrocarbon vapor may exist which is not consumed, but will combine with a heated metal when the two are brought in contact." The furnace consists of an inclined chamber, the lower end of which connects with a horizontal chamber. The ore is fed into the furnace at the top of the inclined chamber. Located under the hopper, and so situated as to direct a flame of gas and air in a downward direction along the inclined chamber, are gas and air burners; any suitable gas and air burners may be used, or burners adapted to operate with a hydrocarbon oil or a producer gas. Located directly under the burners are a series of pushing-screws through which oil pipes pass. These screws push the ore downward along the inclined hearth while simultaneously a certain amount of oil is fed into the ore body. During the passage of the ore downward, it comes in contact with the hydrocarbon vapor from the fuel thus introduced. "This vapor combines with the iron ore under treatment with the result that steel having the required proportion of carbon is directly produced."

W. E. Everette (774,167, November 8) patents a process of direct casting and hardening of metal for armour plates, tool metal, rails, etc. The process may be applied either to pig metal or to the raw ore, and dispenses with the necessity of having to Bessemerize the molten metal. The chief feature is the use of a cyanide as flux. The cyanides employed are preferably the cyanide of calcium (which is the cheapest), the cyanide of soda, and the cyanide of potash. The slag thus produced is valuable as a fertilizer. The operation is as follows: A quantity of pig metal or raw ore is placed in a suitable furnace with the proportionate quantity of flux and heated to about 2800° F. Both the pig metal and raw ore have been previously finely crushed, and the quantities to be used are 60 per cent of pig or ore and 40 per cent of flux. The composition of the flux differs slightly for the ore and for the pig metal. For each the flux consists, preferably, of $\frac{1}{4}$ iron oxide, $\frac{1}{4}$ metallic aluminium, $\frac{1}{4}$ alkaline nitrate, and the remaining $\frac{3}{4}$ carbon and alkaline cyanide. For pig metal two of these five-eighths are cyanide, while for raw ore only one-eighth is cyanide. All of these ingredients are pulverized and well mixed. Fusion is rapid at the stated temperature. When the molten mass in the furnace is ready to pour, the inventor injects into it while still in the furnace, by suitable pressure, a boiling liquid composed of a quantity of molten cyanide of the desired alkali equal to 5 per cent of the charge in the furnace, to which have been added pulverized sulphide of molybdenum, pulverized metallic chromium, manganese, and aluminium in varying quantities, depending upon the purpose for which the metal is to be used. As soon as the high fusion caused by this mixture takes place, the molten mass is drawn off into suitable molds of carbon-lined silica sand. If the material is to be used as a direct casting, it is cooled down to low red heat, about 1000° F., and after scratching the surface of the hot metal free from carbon, dirt, sand and adhering impurities, the incandescent metal is subjected to a spray of intensely cold liquid carbonic acid.

H. B. Atha (774,973, November 15) patents a method for recarburizing scrap steel, containing a small amount of carbon, and for producing therefrom a high-grade commercial steel. This scrap is treated with carbon, but to prevent the

latter from being driven off before it is absorbed by the scrap, the inventor places finely divided carbon into small sacks and mixes these sacks throughout the scrap steel, and presses the two into bundles formed into tubes of about 2 feet in dimension. The bundles so prepared are treated in an open-hearth furnace.

W. B. Burrow (775,026, November 15) patents a mechanical puddling furnace intended to cheapen and quicken the process of puddling and refining iron. The furnace is so constructed that when molten cast iron is placed in the movable hearth, it is given a horizontal movement back and forth on inclined planes or sloping bases forming a part of the bridge-walls. The rapid rise of the oscillating hearth at each end of the furnace and by its sudden stoppage causes the metal to run down the inclined hearth to the opposite end of the same, and is abruptly arrested and dashed against the lining. This action is repeated any number of times, until the iron is brought to the desired condition suitable to be rolled and worked. The sudden and frequent stoppages, and consequently the undulating motion of the iron, exposes it perfectly to the action of the heated gases. The metal as it parts from its carbon becomes finally consolidated into a ball, which is removed to be worked in the usual manner. The operation is assisted by a hollow-toothed combing-bar or rabble extending across the furnace in the direction of its width, which combs or rakes the metal as it passes backward and forward and also prevents the fluid from dashing too violently against the lining, besides acting as a mixing tool. The toothed bar is used at the beginning of the process when the metal is fluid and is withdrawn as the metal thickens.

NICKEL.

R. R. Maffett (774,591, November 8) patents a furnace for reducing and smelting nickel oxides. The oxide is treated in two successive steps: First, roasting of the oxide in admixture with carbon, by which the oxide is reduced partially to metal, and, second, smelting of the oxide and metal on the hearth of a smelting-chamber, by which the reduction is completed; the metallic nickel is withdrawn from the smelting-chamber and cast into molds. Both these operations are carried on in a single furnace with a great saving of fuel and labor. The furnace has an open-hearth smelting-chamber, an elongated reducing-chamber leading therefrom, charging-openings for the reducing-chamber arranged lengthwise thereof, a flue extending beneath the reducing-chamber, and a stack-flue with which the reducing-chamber and flue communicate at their rear ends. The flame from the burners feeding the charge in the smelting chamber passes under the reducing chamber and heats the charge therein to incandescence until it is sufficiently reduced.

ALUMINIUM ALLOY.

R. S. Anderson (773,450, October 25) patents an alloy designed for commercial use wherever ductility is desired in conjunction with lightness and also for use as an anti-friction metal and as a good conductor of electricity. Ninety-three parts by weight of copper and seven parts of tin are heated in a crucible; when fluid two parts of pulverized copper-sulphate are added. The melted mass is poured off into mats or pigs and cooled for subsequent use with aluminium. The proportion of aluminium for general use is two pounds of aluminium to five ounces of the alloy of copper, tin and copper sulphate.

VARIOUS FURNACE DESIGNS.

A. P. O'Brien (775,147, November 15) patents mechanical details of construction of the well-known general type of roasting furnaces containing a series of floors of brick with charge openings in each floor to the next one below, the discharge openings being alternately at the circumference, and at the center of the floors, while a central shaft carries rabbles for stirring the ores upon the floors so as to move them

from one floor to the other. This patent refers to various mechanical details of construction.

H. Cockell and W. H. Fish (772,925, October 25) patent a roasting and smelting furnace as shown in Fig 1, the lower left-hand figure being a sectional view of the furnace on the

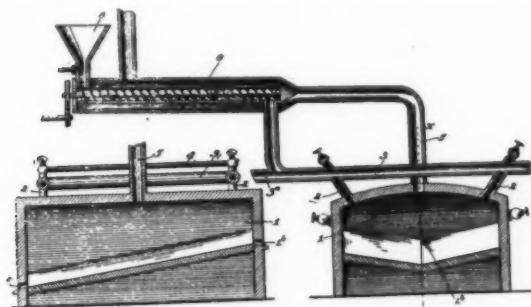
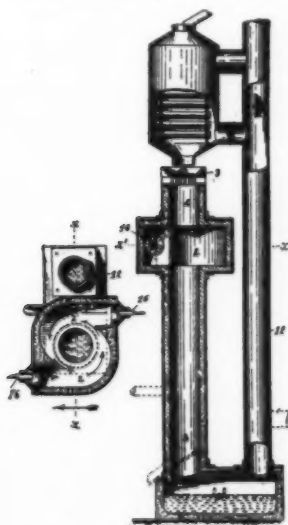


FIG. 1.—FURNACE DESIGN.

plane indicated by the line *x-x* in the right-hand figure. 1 is the furnace, which has an inclined trough-like bottom, with a tap 1b to discharge the slag and the top 1c to discharge the metal. Connected with the fuel and ore-inlets 2 are pipes 3, air being supplied through 3a, while 4 are oil or gas pipes, 6 is an ore-feeding and roasting-chamber containing a conveyor. The ore is fed through the hopper 8 into this chamber and then passes through 3 into the furnace. The ore is roasted in 6 by the hot gases escaping through 5 from the furnace, there being no direct connection between 5 and the ore in the roasting chamber.

H. F. Brown (774,930, November 15) patents a process for reducing ore in a stack furnace, as shown in Fig. 2, with



the use of hydrocarbon fuel, such as oil or gas, or of powdered charcoal, coke or coal dust. The essential feature is that the ore first passes in a finely divided condition through a high heated, non-whirling atmosphere. The necessary fluxes are added previous to charging the ore. The second step resides in subjecting the particles as they pass beyond the zone of the oxidizing atmosphere to the action of a whirling reducing atmosphere which conveys the ore downward through a reducing zone of the stack within which the ore is being treated. This atmosphere is so regulated that as it passes down the stock of the furnace a vortex is formed which brings the segregated particles together, which vortex also forms and maintains a zone of concentrated heat so that instant combination and fusion takes place. 2 is the combustion chamber, the burners 16 for the oil being so arranged that the flame is given a spiral motion which will follow down the shaft. The zone of reduction within the furnace shaft exists between the points *a* and *b*, while the atmosphere maintained between the vibratory feed-plate 3 and the combustion-chamber 2 is the highly-heated, downwardly-moving, non-whirling atmosphere to the action of which the ore is first subjected during its travel through the stack.

K. Schneider (774,788, November 15) patents details of

construction of charging apparatus for blast furnaces. In furnaces with inclined skip-hoists the disadvantage arises that if the hoist gets out of order, the charging can only be effected with the greatest difficulty. The inventor connects the furnace tops of two contiguous furnaces by a conveying device, by means of which the ores and other materials can be conveyed from the mouth of a furnace whose hoist is in working order to a contiguous furnace whose hoist is out of order.

A. C. Calkins (774,232, November 8) patents details of construction of an assayer's furnace containing a crucible chamber and a muffle, for the use of liquid fuel.

CLEANING BLAST FURNACE GASES.

In the utilization of the blast furnace gases for driving gas engines—which is making slow but steady progress in this country—it is most important to remove dust and the like from the gases. A. G. McKee (774,851, November 15) patents apparatus for this purpose. It is essentially a fan which imparts a rapid rotary movement to the gas by which all non-gaseous material, such as coke, ore, etc., is forced outwardly by virtue of the centrifugal force, and drops into a special chute.

Current Notes.

BETTS PROCESS OF LEAD REFINING.—The Canadian Smelting Works in Trail, B. C. (see paper of Mr. A. G. Betts, in our September issue, 1903) are rushing the addition to their old electrolytic lead refinery to make it a fifty-ton plant. They are at present refining over 20 tons a day, with fine results. They are working up part of the lead into lead pipe, and are supplying the Canadian trade with from ¼-inch to 3-inch lead pipe. An interesting new development is that they have contracted for the erection of a white lead plant in Montreal, where Betts electrolytic lead will be corroded. A carload of lead was sent to the Carter white lead works, where a test was made. The results were most satisfactory, as a very high-grade white lead was obtained, a much whiter product than that made from ordinary refined lead.

FARADAY SOCIETY.—The Council of the Faraday Society announces that the society will in future publish its own Transactions, instead of including them in the *Electrochemist and Metallurgist*, which has heretofore been the organ of the society since its inception. The society will issue in future quarterly Transactions, containing in full the papers which have been read before the society and the discussions thereon. In addition there will appear monthly Proceedings, containing reports and notices of meetings, abstracts of the papers read during the previous month, and of the discussions thereon, abstracts of electrochemical patents, and the physical chemistry section from Science Abstracts. All papers will be printed before they are read, and sent in proof form to every member of the society. The first volume of the Transactions will appear about the end of the present year.—The *Electrochemist and Metallurgist* has in the meanwhile suspended publication; the publisher intends to issue, beginning with next year, a monthly publication entitled *Metals*, with which the above-named journal will be incorporated.

NEW PUBLICATION.—The first number of a new journal with the title *The Chemical Engineer*, a monthly journal of practical, applied and analytical chemistry, has just been issued. It is published by the Chemical Engineer Publishing Co., of Allentown, Pa., Mr. Richard K. Meade being the editor. The first issue contains the following articles, among others: Valuation of Coal for Steaming Purposes; Tests for Wood Paving Blacks, by F. A. Kummer; Determination of Lime in Limestone, Cement, Etc., by R. K. Meade; Carbon Combustion Apparatus, by P. W. Shimer; Silica Determinations, by H. E. Ashley; Protection of Structural Work from

Rust, by R. Job; Bismuthate Method for the Determination of Manganese, by A. A. Blair. We wish every success to our new contemporary.

PYROMETRY.—The importance which thermodynamical reasoning has assumed in the development of modern physical chemistry, has emphasized the fact that the temperature is a factor of fundamental importance in determining the reaction which goes on between given reagents. The importance of this fact has always been recognized to greater or less extent by practical metallurgists and chemical engineers. The necessity of controlling the temperature required exact methods of measuring it. With the arrival of the electric furnace the temperatures available to the chemist and metallurgist were very considerably raised and the difficulties of temperature measurements were correspondingly increased. Dr. C. W. Waidner, of the National Bureau of Standards, has rendered most useful service to the industries by summing up the more widely used methods of pyrometry in a very lucid and concise way in a paper read before the Engineers' Society of Western Pennsylvania. The paper is printed in the September number, 1904, of the Proceedings of this Society, and has recently been issued in form of a pamphlet of ninety pages. The subject is discussed under the following headings: Expansion pyrometry (solids and gases), specific heat pyrometry, thermo-electric pyrometry, electric resistance pyrometry, optical pyrometry, and transpiration and viscosity pyrometry. In each class the fundamental types of apparatus are described, illustrated and discussed. The bibliography of 133 original papers should be greatly appreciated by those wishing to study the problem to a greater extent.

REFRACTORIES.—We have received from Messrs. FitzGerald & Bennie, of Niagara Falls, two interesting samples of a material which they recently turned out from an electric furnace run. The samples are virtually fused magnesia, as the original material was magnesite. They are instructive in showing the effect of very high temperatures on some of the materials which are considered good for ordinary types of furnaces, but which break down with the higher temperatures of the electric furnace.

Book Reviews.

MONOGRAPHS ON APPLIED ELECTROCHEMISTRY.—Vol. I.: *The Electrolysis of Water, Processes and Applications.* By Victor Engelhardt. Authorized English Translation by Dr. Joseph W. Richards. Easton, Pa.: Chemical Publishing Co. 140 pages, with 90 figures and 15 tables in the text. Price, bound, \$1.25. Vol. III.: *The Production of Chromium and Its Compounds, by the Aid of the Electric Current.* By Dr. Max Le Blanc. Authorized English Translation by Dr. Joseph W. Richards. Easton, Pa.: Chemical Publishing Co. 122 pages. Price, \$1.25.

The original German editions of these two books were reviewed on pages 75 and 261 of our first volume.

By undertaking the translation of selected volumes of this series of German monographs into English, Dr. J. W. Richards who has already done so much for the promotion of electrochemistry in this country, is rendering a most useful service to all interested in electrochemical progress. This series of German monographs is being prepared and edited undoubtedly with skill and with due respect to those points which are most important from an engineering and industrial point of view, and while the United States with the abundance of valuable metals is naturally leading the world in electrometallurgy, yet there are certain applications of electrochemical methods about which we can still learn from Europe. The electrolytic preparation of oxygen and hydrogen is an example. There

are abroad quite a number of manufacturers of apparatus for this purpose, while we do not know of any in this country. The reason is probably that our manufacturers do not consider this a matter of sufficiently large importance; on the other hand, reports from abroad seem to indicate a continuous increase of the use of electrolytic hydrogen and of hydrogen and oxygen in the oxy-hydrogen flame for soldering and welding purposes in various metallurgical industries. It seems, indeed, quite certain that the influence of electrochemical methods and products will make itself more and more felt in the near future in the most unexpected quarters of engineering. For all who are not electrochemists themselves, but who want to apply a method of an electrochemical nature for a certain purpose, these monographs, each dealing with a distinct limited subject, should be most valuable. Finally, we quite agree with the translator, that electrochemists will find these monographs rich in suggestions of ways and means for accomplishing difficult ends, so that they are of far greater value than mere codes of operations for producing hydrogen and oxygen, and for making chromium and chromium compounds with the aid of the electric current.

JAHRBUCH DER ELECTROCHEMIE, Berichte über die Fortschritte des Jahres, 1902. Edited by Dr. Heinrich Danneel. Halle: Wilhelm Knapp, 1904. 750 pages, price, marks 24.00.

This is the ninth annual appearance of this indispensable volume, and the work done on it is more thorough than ever before. It is the fault of the reviewer, for which he apologizes to the publisher, that this volume was not reviewed several months ago, when first received; it is the fault of someone abroad that the review of 1902 was not published until 1904, for which delay we fear that the publisher will be the principal sufferer.

However, there is every reason why this volume should share in full measure the popularity and sale of its predecessors. The author has had the assistance of Doctors Askenasy, Borchers, Elbs, Harms, Mugdan, Sackur and engineer von Kügelchen, of which the latter is now an American. The division of the subject is logical and satisfactory, the working out of each section thorough, the literature, compilation complete, and the indices above criticism. Altogether, one can feel assured that in this volume is to be found a record of every published article on electrochemistry which appeared during 1902, carefully and intelligently abstracted.

PYROMETERS SUITABLE FOR METALLURGICAL WORK.

(Continued from page 472.)

4. *The Roberts-Austen Recording Electric Pyrometer* (made by Messrs. James Pitkin & Co.)—This instrument, which is of the recording electrical type, was devised by the late Sir William Roberts-Austen for the continuous registration of very high temperatures, and it is widely used for recording the temperature of the hot blast and for regulating the heat of metallurgical furnaces. The apparatus consists of two mahogany cases impervious to light, the larger of which contains a Holden d'Arsonval dead-beat galvanometer, with a suitable arrangement of lenses and mirrors. The other case contains a drum which is made to revolve by clockwork once in 24, 12 or 6 hours. The surface of this drum may be covered with sensitized photographic paper. A ray of light, either from a gas jet or from a lamp, is thrown by means of a mirror at an angle of 45° on to the mirror of the galvanometer, and is projected thence to the surface of the drum, acting photographically on the sensitized paper.

The galvanometer is then connected by copper leads to a thermo-junction inserted in the space or object, the temperature of which it is desired to record. The thermo-junction may, for example, be placed in a hot blast main or in the midst of a small mass of metal which is either being cooled from a

high temperature or is being raised to a temperature below that of the melting-point of platinum. The heating of the thermo-junction causes a very small current to pass through the coil of the galvanometer, which is deflected, and the mirror attached to it projects a spot of light on the surface of the drum. The amplitude of this deflection indicates the temperature, and a continuous curve is traced on the photographic paper, which at once indicates what temperature is attained at any particular moment. A scale is also provided on which the temperatures can be read from time to time, without interfering in any way with the record. The most simple of the standard forms (pattern 1) is provided with a switch or handle, by means of which a record from any one of six furnaces or centers of heat may be obtained. The time devoted to the record of any of the six depends upon the length of time the handle is left at a definite part of the switch. The number of the particular furnace under examination is automatically registered on the drum. The second form of the instrument (pattern 2) enables two continuous and simultaneous records to be taken on the same drum from two furnaces, provision being made for distinguishing the curves. The change from one furnace to another is made automatically by means of clockwork. The third form (pattern 3) is for taking three continuous and simultaneous records.

Thermo-junctions have been used from time to time since 1826, when Becquerel advocated their adoption. Confidence in their indications was, however, only established when it became possible to obtain a good dead-beat galvanometer. The particular thermo-junctions to be used will vary with circumstances, and for many purposes the platinum-platinum-iridium junction, first used by Prof. Tate in 1873, possesses many advantages over other thermo-junctions. Specially designed electric recording pyrometers are also constructed by the same makers for research work, similar to those used at the Royal Mint, where extreme accuracy is required in determining temperatures. In this pattern two galvanometers are employed, one of greater sensitiveness than the other, in a case impervious to light. A ray of light either from a gas jet or from a lamp is thrown, by means of a mirror at 45° (having been focussed by suitable lenses), on to the galvanometer mirrors, and is projected thence on to the surface of a photographic plate. This plate is raised at any desired speed by means of an accurately constructed clockwork train, and the rays of light from the galvanometer mirrors, reduced by means of a horizontal slot to mere points of light, fall on to the sensitized surface, which, being developed, gives an accurate record of the temperature at every instant of time. A dark slide or plate carrier is provided for enclosing the plate, to enable it to be removed to the dark room for development.

(To be concluded.)

THE ELECTRIC PRODUCTION OF OZONE AND STERILIZATION OF WATER BY OZONE.

Besides electric furnace processes and electrolytic processes, a third method of producing chemical effects by means of electricity has attracted considerable attention in recent years. These are the effects produced in gases by electric discharges through the same. There is considerable difference between different processes of this kind, according to the nature of the discharge required for the special purpose. For instance, for the fixation of atmospheric nitrogen it is necessary to produce arcs, while in the production of ozone from atmospheric oxygen, silent electric discharges are utilized and arcs must be avoided.

A summary of the different processes for making ozone by electric discharges through air, and for the subsequent use of ozone for the sterilization of water, was given on pages 65 and 426 of our present volume, where references to various descriptions of apparatus of this kind may also be found.

Among ozonizers, that of A. VOSMAER, a Dutch electrochemist, should be of special interest at present, for two reasons: Firstly, because no solid dielectric is used, so that there is no danger of breakage of glass, etc. Secondly, because this process is to be introduced in the United States by the United Water Improvement Co., of Philadelphia, Pa., who have acquired the American rights of this system. This company has recently published a very full report by Mr. J. J. DE KINDER, who has made a full investigation of the process in Holland. From this report the following information is taken.

The plant using the Vosmaer process is located at Nieuwersluis on the River Vecht, between the cities of Amsterdam and Utrecht. This river is one of the most polluted waters in Holland. The water-ozonizing capacity of the plant is equal to 20 cubic meters per hour, or, in round numbers, 5300 gallons.

The water to be ozonized is conveyed by means of a pump from the Vecht to a Kronsche rough filter, and from there to the top of a standpipe, having a diameter of 15 inches and a height of 35 feet, down which standpipe it flows on its way to the receiving reservoir located outside of the building.

Air is drawn by means of an air pump from an iron tank, in which are shelves with chloride of calcium, and issues from the tank in a dry condition, the chloride of calcium having absorbed the moisture which it contained before entering the tank.

On its way to the suction side of the pump the air passes through the ozonizer, an apparatus consisting of a number of light copper tubes, each about three inches in diameter and 16 feet in length, the tubes being supported at either ends in headers in the manner of an ordinary closed feed-water heater), the air discharge pipe from the drying tank connecting with the header at one end of the ozonizer, and the air suction pipe to the air pump with the opposite header of the ozonizer. The pump compresses the air to slightly above atmospheric pressure and delivers it in the bottom of the

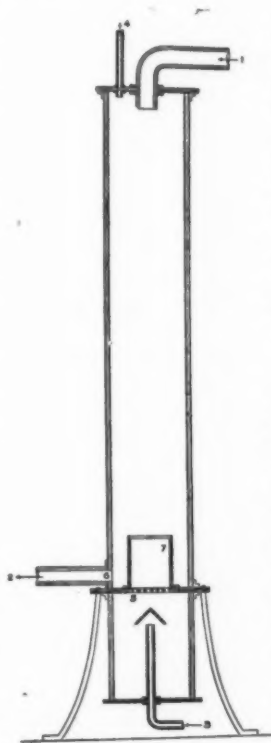


FIG. 1.—STERILIZER.

standpipe already referred to, in which it ascends, distributing itself in minute globules through the descending water.

From one and one-half to two grams of ozone per cubic meter of water pumped are used; one kilowatt-hour of electrical energy produces 15 grams of ozone; the quantity of ozonized air required for the ozonizing of the water is in proportion of about one and eight-tenths volumes of atmospheric air to one volume of water.

The general arrangement of the sterilizer is shown in Fig. 1. The water enters at 1 and passes out at 2, while the ozone enters underneath at 3 and passes out at 4, the ozone having completed its work and having again been changed to oxygen. The apparatus works continuously and entirely on the counter-current principle, which is naturally the most economical. A peculiar construction of the lower part, shown in Fig. 1, makes it impossible for the water to enter into the ozone supply, and prevents the ozone from passing out with the water. The first is obtained by the presence of the perforated plate 5. As long as there is sufficient pressure, water can-

not possibly pass, on the principle of the bottom of a Bessemer converter. The second is obtained by the presence of the perforated wall 6 and the screen 7.

A large amount of information is given on the results obtained in extensive tests of ozone-sterilization of water. The conclusions reached by Dr. Ohlmuehler and Dr. Prall, of the German Imperial Board of Health, are specially noteworthy, and are given as follows: By the treatment of water with ozone a remarkable destruction of bacteria is produced, and in this regard ozonizing is in general superior to separation

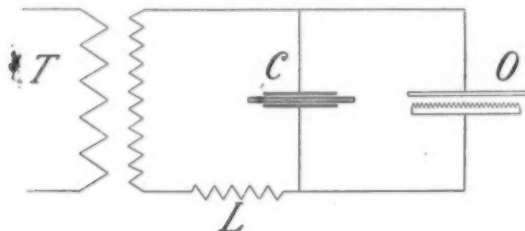


FIG. 2.—CONNECTIONS FOR PREVENTING ARCS.

of bacteria by sand filtration. The cholera and typhus bacilli are destroyed. Viewed from a chemical point of view, the water is affected only in so far that the oxidability is reduced and free oxygen increased, both of which mean an improvement of the water. The ozone which is introduced in the water is of no importance from a technical or health-affecting consideration, as it readily changes into oxygen. The treatment of it improves the water by making it colorless. The taste is not affected, etc.

Mr. Vosmaer claims his plant to require a minimum of attendance, and that it is practically self-operative. During the entire tests the only attention required was the keeping of steam to workable pressure, and examining once a day the oil cups on the movable parts of the pumps, etc.. In other words, the plant practically ran itself.

The main point of interest for electrochemists is the production of ozone by silent discharges through atmospheric air. It has long been known that the chief point to be taken care of is the prevention of sparks or arcs. It is only the silent or brush discharge which causes the oxygen of the air to be changed to ozone. Most other systems take recourse to solid dielectric, glass being generally used; this is, for instance, the case in the ozonizer of Siemens and Halske. The danger is here that the glass, becoming heated, turns to slightly conduct the electricity, and a destructive spark is then liable to result.

FIG. 3.—DETAILS OF CONSTRUCTION OF OZONIZER.

In the Vosmaer system there are no solid dielectrics between the points of discharge, neither high frequency nor high resistances nor rotating electrodes, but the brush discharge is produced by using sharp-pointed discharges against flat electrodes and the voltaic arc, by special way of connecting up, is absolutely prevented. In Fig. 2, T is an ordinary step-up transformer, C is a high-tension condenser, L is a

high-tension choking coil, and O is the ozonizing apparatus. The high-tension alternating current from T is shunted by the condenser, while the choking coil is in series with the line. In this way an arc discharge at O is made impossible.

The ozonizing apparatus per se is simplicity itself. There are no moving parts; no fragile material is employed and no cooling whatever is resorted to. The ozonizer consists of a number of tubes put together something like a feed-water heater, as shown in Fig. 3. In each tube, *d*, there is a complete set of dischargers, viz: one flat, *a*, and one pointed, *b*, separated from each other at a fixed distance by insulated stems and forks, *c* (made of porcelain). There is nothing out of the ordinary about the transformer or choking coil, but the condenser is of special manufacture. Its general outline is shown in Fig. 4, and if made with care it never gives rise to any trouble.

Fig. 5 shows the general arrangement of all the apparatus. FI means the rough filter from which the water, by means of the pump WP, goes to the top of the sterilizer ST and leaves by the valve V. The air enters through the air-dryer AD, goes through the ozonizer OZ, and by means of the pump OP is forced into the bottom of sterilizer ST.

An ordinary generator DY delivers alternating current to a switchboard SW, from whence it goes to the step-up transformer TR (earthed), and from here to the ozonizer OZ (earthed).

When once properly started the plant requires hardly any attention. The only question of importance is the determination of the amount of ozone required for the particular water to be treated. There are two methods for determining whether the quantity of ozone supplied be sufficient or not. First, by testing the surplus of ozone at the outlet of tube 4 in Fig. 1, by iodine of starch paper. Second, by the sense of smell. As long as there is ozone left it is certain that there

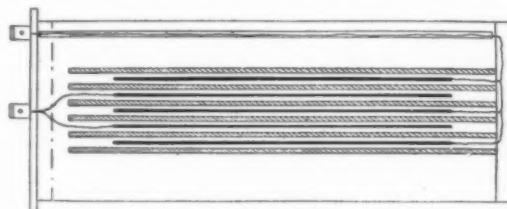


FIG. 4.—CONDENSER.

has been sufficient to destroy the bacteria, and if more absolute certainty is desired, there is still another way, viz: determining by chemical means the quantity of soluble organic matter oxidized. Experience, however, is a safe guide, and there is no special skill required at Nieuwersluis to run the plant. Any engineer of ordinary intelligence can do so.

The main conclusions reached by Mr. de Kinder are: "First, that filtration alone can, in addition to clarifying water, effect purification of the same, only to a degree varying with construction, maintenance, supervision, etc., of the plant; and, secondly, that by ozonizing a previously clarified water absolute purity is obtained." Hence, the belief is expressed that "as an adjunct to any filtration system, sufficiently efficient to produce clear water, sterilization by ozone will prove to be one of the greatest blessings of this century."

An experimental plant, using the Vosmaer system, is now being erected by the United Water Improvement Co. on the Schuylkill, near Philadelphia. The building is almost finished, as is most of the machinery, and it is expected that it will be in running order at the beginning of December. At this plant, polluted water will be taken from the Schuylkill, at a point below the intercepting sewer and below the slaughter-houses and manure yards. A million gallons of water are to be treated per day; they are to be first passed through a rough filter and then subjected to the Vosmaer system of ozone sterilization.

THE WORKS OF THE POWER AND MINING MACHINERY COMPANY.

The plant of the Power & Mining Machinery Co., at Cudahy, Wis., has been designed so as to embody all the latest developments and achievements of shop management and operation. As it stands, it has all the modern labor-saving devices that could be adopted. The buildings are arranged with reference to each other, so that there shall be the least handling of material, and the arrangement of machinery in it has been carried out with the same idea uppermost.

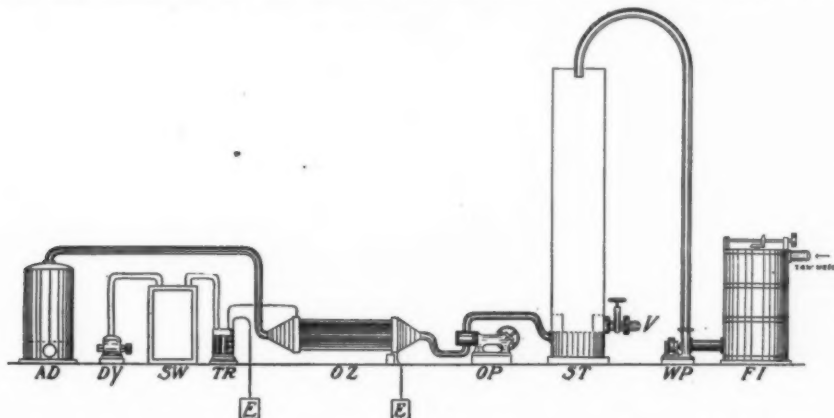


FIG. 5.—GENERAL ARRANGEMENT OF PLANT FOR STERILIZING WATER BY OZONE.

Where it is necessary to handle material, the latest devices, usually overhead cranes, are installed.

The plant was designed for the construction of Loomis-Pettibone gas apparatus, American Crossley gas engines, and mining machinery. Its most novel feature is probably the power house. This consists of products of the plant itself, namely, Loomis-Pettibone gas producers furnishing a supply of gas for operating the American Crossley gas engines, direct connected to General Electric dynamos. Water gas is also generated for use in forges and furnaces.

In the construction of the buildings, the question of light and ventilation was given special attention. Connecting the buildings is a net-work of railway tracks, which greatly facilitate the handling of material. In the separate buildings these run under the crane ways so that the cranes may lift the heavy parts from the cars and set them where desired.

The office building is occupied by the offices of the plant, the private telephone exchange and the engineering department, with a drawing room. Immediately to the rear of this building is the machine shop, which is the largest of the group of buildings. The total length is 552 feet, its greatest width 162 feet. The shop is fully equipped with modern machinery. In the selection of the machines, special effort was made to obtain those necessitating a minimum amount of chucking. All are driven by General Electric motors. Where convenient, line shafting has been erected, and one motor operates a group of several machines. In such cases, to economize space, the motor is placed overhead. The larger machines, however, are driven separately. Sometimes the motors are geared to the machines direct. Often belts and counter shafts are employed.

Buildings nearby situated contain the forge room, the sheet metal shop, the pattern shop, the pattern storage building and the foundry. The foundry is equipped with a large cupola furnace with draft by a Connersville Blower Company blower, electrically driven. Iron and fuel is conveyed to the furnace by means of the railway along the south side of the foundry, and is raised to the charging floor by means of a motor-driven elevator. The foundry is supplied with three overhead cranes, which serve the entire floor. The two on the main craneway have a span of 65 feet, and are 30 and 15

tons capacity. The larger is provided with a 5-ton auxiliary hoist. An 8-ton crane with a span of 40 feet, serves the remainder of the foundry. Casting weighing 50 tons have been poured in the foundry. Two large ovens are built into this foundry near the southeast corner. A small lean-to at the northeast corner contains the rattlers. For blowing out molds, running molding-machines and shipping castings, compressed air pipes are dropped down posts at convenient points. To steady the supply of air piped from the power house, a storage tank is placed in the foundry.

THE POWER PLANT.

The power plant, which furnishes a working exhibit of the products manufactured by the company, is located in an L-shaped brick building in the extreme northwest corner of the yard. The extension on the south contains the Loomis-Pettibone gas producers, boilers, controlling mechanism and coal-handling apparatus. The eastern extension is occupied by the American Crossley gas engines, generators and switchboards and a gas engine driven air compressor. At the juncture of the two extensions is a room containing

the scrubbers, exhausters, feed-water heater and a small auxiliary boiler. The gas holders, cooling basin and dry scrubber are located in the angle between the two portions of the building.

Either producer or water gases are generated from the same apparatus. A portion is piped direct to the engines in the generator room, and pipes are also laid to the furnaces of the forge and boiler shops, and to the testing floor in the machine shop. The wing containing the producer is provided with an intermediate or operating floor.

Four producers, having a total capacity of 2000 hp., are provided. These are divided into two generating sets. Two producers operate in connection with one boiler and form a set. The two sets may be operated independently. Each producer measures 9 x 15 feet, and is connected near the base through a 30-inch valve provided with hydraulic control to the boiler operating with it. The boilers, which measure 5 x 23 feet, are set vertically, and are designated much after the pattern of an ordinary fire-tube boiler, the hot gases from the producer passing through the tubes. Leading from each boiler are two gas mains, that for the producer gas being 24 inches, while the other, for water gas, is 20 inches in diameter. The mains from each of the boilers lead to the bottoms of one of the two wet scrubbers located in the corner room. A main leads from the top of the producer gas scrubber through the engine-driven exhauster. The discharge from the exhauster is 20 inches, and, according to the position of the controlling valve, leads either to a purge stack exhausting into the atmosphere, or to the dry scrubber located outside the building. A by-pass, which may be used as occasion may require, is provided around this scrubber. A short length of 20-inch main connects the dry scrubber to the producer gas holder which is of 10,000 cubic feet capacity. From the top of the water gas scrubber a 16-inch main goes direct to the water gas holder of the same capacity as that for producer gas.

The gas from the producers in passing through the boiler on its way to the scrubbers, generates steam which is used for several purposes. In making water gas, it is introduced direct into the bottom of one of the producers. A limited quantity is also supplied above the fires of the producer, when producer gas is being generated. A 2-inch steam pipe leads to the en-

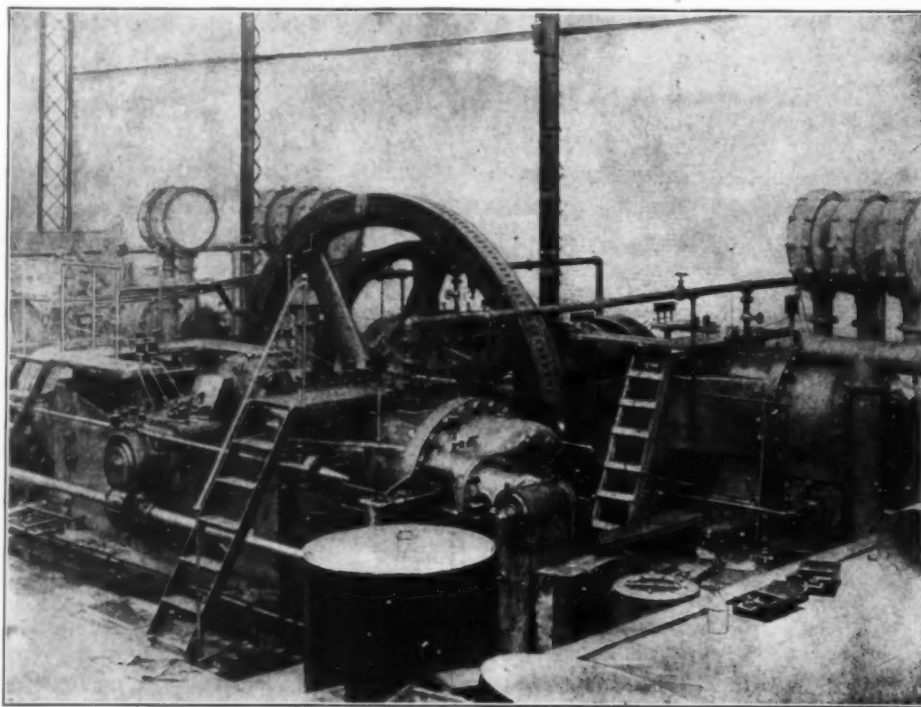
gine operating the exhauster. The boiler feed pump working in connection with the feed-water heater, as well as the pump supplying pressure for the hydraulic valves, are also operated by steam.

A 6-inch water main from the water system of the plant enters the power house; a 2½-inch pipe is tapped from this and leads direct to the water-cooled valves between the generators and the boilers. Another branch passes to the 6 x 4 x 6 inch pump maintaining pressure for operating the hydraulic valves. Water is also supplied to two circulating systems of cooling water. One of these extends between the cooling basin and the scrubbers in which the gas is cooled and cleansed. A direct-connected electrically driven pump located near the west wall of the engine room discharges through a 4-inch pipe leading to the top of the two scrubbers into which the water is thrown, in the form of a spray. The water having fallen down over the layers of coke in the scrubber, it flows out of the bottom of the scrubbers to the western end of the cooling basin, and after its temperature is reduced, it is again pumped through the circuit. A similar pump, also motor-driven and placed near the scrubber pump, circulates water through the jackets of the engines. A 6-inch discharge from the pump runs the full length of the engine room, taps leading to the water jackets of the engine being taken off at frequent intervals. The discharge pipe continues through the engine room and to the testing floor in the machine shop. The returns from the jackets pass to the eastern end of the cooling basin shown in the engraving. The two portions of the basin are divided by a solid partition to prevent the mixing of the water of the two circulating systems.

To start the plant when cold, the producers are filled with coal to a depth of about 5 feet. This is lighted at the top. The exhauster is then started, steam from the engine being obtained from the auxiliary boiler. The down draft produced by the exhauster soon ignites the mass of coal. More fuel is then added until the bed is about 8 feet thick. While the fire is getting under way, the gas being of an inferior quality, is allowed to pass off into the atmosphere through the purge stack mentioned. After the fires have assumed the proper heat, the purge stack is closed, a limited quantity of steam is admitted above the fires, and the producer gas generated is exhausted into the holder. If desired, producer gas may be made continually, but usually the requirements of the furnaces and forges are such that the generation of producer and water gases is alternated at periods of from 10 to 20 minutes. To make water gas, a few changes are necessary. The charging doors of the producers are screwed down tightly. The water gas scrubber is connected with the boiler and the connection with the producer gas scrubber closed by the operation of hydraulic valves. The 30-inch valve between the boiler and the bot-

tom of one of the producers is also closed. Steam is then admitted to the bottom of the producer, whose connection with the boiler has been closed. The pressure forces it up through the fire of the producer, through a pipe connecting the two producers at the top and down through the live coals of the other producer. It then passes as gas through the boiler and scrubber to the gas holder.

The steam soon cools the fires to a point at which they do not decompose the steam. The proper valves are then opened and closed and producer gas is generated until the fuel is brought to incandescence. When water gas is again generated, steam is introduced into the second producer, and its path through the two producers is thereby reversed. This enables the raw steam to come in contact with the fire least cooled by the previous operation. As stated before, two producer sets are installed. One is run until the ash or clinker



1400-HP. GAS ENGINE

in the producer limits its capacity. The other set is then fired, the scrubber connection to the old set being closed. By means of the cleaning doors at the grate level, the old producers are then emptied and cleaned, when they are again filled and are ready to be fired. About 80 tons of bituminous coal can be consumed before cleaning is necessary.

The engine room is to contain three 22 x 30 inch two-cylinder American Crossley gas engines, each direct connected to a 150-kw., 250-volt, direct-current generator. A smaller engine of the same general design will operate an air compressor supplying air to the surrounding shops. Gas for the engines will be supplied through a 20-inch main. The connections are such that either all water gas, all producer gas or any desirable mixture of the two may be supplied to the engines.

The leads from the dynamos will be run through vitrified clay conduits under the cement floor to the switchboard located along the eastern wall of the engine room. This contains three generator panels and several feeder panels through which are distributed the sixteen lighting and power circuits leading to the several shops. In all, about 50 motors, varying in size from 50 to 3 hp., are employed. The greater of these

are of about 28 to 30 hp. The power load is about 66 per cent of the total, the remainder being consumed in the 250 arc lamps used in lighting the shops.

GAS ENGINES.

The American Crossley gas engines, manufactured by the company, are made with single cylinders up to 150 hp. Two cylinder engines range in power from 180 to 645 hp., while those of four cylinders are rated at from 360 to 1400 hp. and larger. The engines are assembled and tested in the western portion of the machine shop.

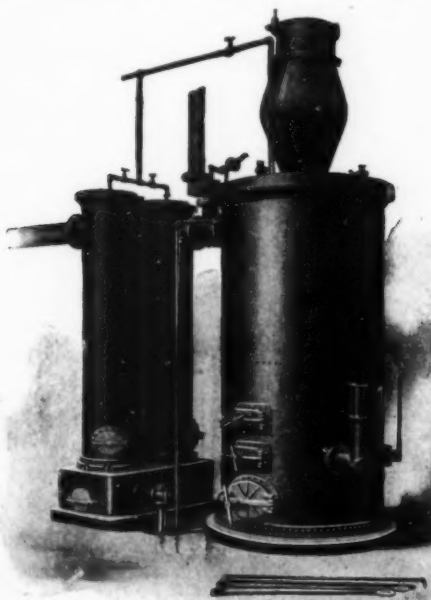
In one of the views, a four cylinder engine is shown on the test blocks. This was built for the Elmira Water, Light & Railway Co., of Elmira, N. Y., and will be direct connected to the generator. The engine is rated at 1400 hp., and has a 36-inch stroke, the cylinder diameter being 32 inches. A fly-wheel 13 feet in diameter is provided. A notable feature of the engine is the method of constructing the water jacket. The inner metal surrounding the combustion chamber is cast separate from the outer. Lugs are cast on the outer and inner walls of the two shells. These are drilled and tapped, and binding stays inserted, which tie the shells together. This method of construction is used in order that casting strains, blow-holes and other defects may be avoided.

Each cylinder is fitted with a weighted fly ball governor, which varies the mixture in the cylinder according to the load carried. A safety gear prevents the engine starting in the wrong direction. Ignition is accomplished by a double ignition tube arranged so one tube may be renewed while the engine is operating. The entire oiling system drains to the crank pit. The engine is built under a guarantee of speed variation not to exceed 2 per cent from the mean.

A SUCTION PRODUCER.

Another of the products of the plant is shown erected in the machine shop. This is a 100-hp. Crossley suction gas producer.

The producer proper consists of a cylindrical shell lined



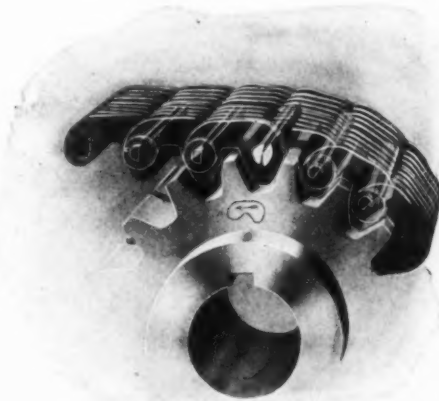
SUCTION GAS PRODUCER.

with fire brick and fitted with a revolving grate. The gas, after passing to the top of the producer, enters an evaporation, where heat is transferred from the gas to water forming steam, which enters the bottom of the producer. A hydraulic box, through which the gas next passes, prevents

the gas backing up into the producer. It then flows through a coke scrubber, where it is cooled and cleaned, and then through one of sawdust, to remove any fine ash or other solid matter which may have been drawn through from the producer.

THE SILENT CHAIN FOR DRIVING MACHINERY.

The introduction of the silent chain drive has broadened the field for motor driving, which is now of such importance in



SILENT CHAIN CONSTRUCTION.

any shop management. The silent chain has all the advantages of flexibility and smoothness of drive, inherent in the belt drive, and to this is added the positiveness of drive which belongs to gearing.

The Morse Chain Company, Trumansburg, N. Y., has made a special study of the application of silent chain driving to severe and limiting conditions, which have given trouble with any other method of driving. As a result, they have perfected a chain for machinery driving which is adaptable to any class of service whatever; it is not affected by high-speed, very hot or dry atmosphere, or moisture, and will run satisfactorily with but little lubrication. It is found in practice to not wear rapidly even when subjected to the most severe extremes of dust, dirt and grit imaginable. The important feature is that its efficiency in transmission of power is very high, being by actual test from 98½ to 99 per cent.

The accompanying illustration of two chain drives, operating from a motor-driven shaft to drive condensing pumps, shows the use of the positive and noiseless drive under conditions where a belt could not possibly be used. These chains were introduced here to replace the gears formerly used, on account of their noisy action. The maximum pull on the chain is 10,000 pounds, which alternates to 300 pounds negative pull at each stroke, due to the intermittent action of the pumps, but over two years' service shows no depreciation.

Concerning the construction of the chain drive the following remarks may be made. The joint consists of two pieces of hardened tool steel, so shaped and arranged that, as the joint works while passing on and off the sprockets, one piece rocks or rolls on the other. The two rocking parts of the joint are fixed in opposite ends of the links, and as there is only a pure rolling friction on hardened tool steel surfaces with ample contact area to withstand the pressure, there is no tendency for the joint to wear and cause the chain to lengthen. To prevent undue vibration under high speeds and the consequent wear, the rocker pins of the high-speed silent running chain are so shaped that the areas of contact surface are greatly increased when the chain is drawn straight between sprockets, in which position a broad bearing is given. Th-

two-part pin used in the Morse rocker joint permits of an unbroken contact the whole width of the chain, less the outside links, which results in nearly doubling the length of the bearing surface over a chain with a single-pin joint.

As the rocker joint is subjected only to rolling friction it does not require lubrication, and the speed limit is therefore not fixed by the point at which the centrifugal force will throw off the lubricant. A paste grease, sufficiently heavy so that it will not be thrown off at high speeds, affords proper lubrication for the chain in its contact with the sprocket teeth and between the plates of the chain itself. As the pressure between the chain and the sprocket teeth is inversely proportional to the number of teeth in contact with the chain, and as this number is large, the pressure is small, and very little wear will take place.

With the increasing use of machine tools in all manufacturing shops, a study of this important branch of the subject will be profitable. Under shop conditions, where the question of motor-driving is simplified by the presence of

The ST. LAWRENCE RIVER & POWER Co. has issued an extremely handsome and nicely illustrated book, descriptive of the power plant, the town of Massena, in which it is located, and a few of the industries already using the power. Most notable among the latter is the Pittsburgh Reduction Co., which has purchased a large plot of ground from the Power Co. and has already erected buildings thereon costing \$1,200,000; in one of these buildings alone, 12,000 e. h. p. is used, and another contains the most modern wire-drawing and insulating plant in existence. The Pittsburgh Reduction Co. is constantly extending its plant and will eventually use 50,000 hp.

We have received from Messrs. E. H. SARGENT & Co., of Chicago, their fully illustrated catalogue of chemical apparatus and assayers' materials. It is a handsomely bound volume of 238 pages, and deals with apparatus and instruments of all kinds, for use in chemical laboratories and plants, including balances, all kinds of glass apparatus, burners, cement-testing apparatus, calorimetric carbon apparatus, combustion apparatus, condensers, crucibles, desiccators, distilling apparatus, extraction apparatus, filters, all kinds of furnaces, apparatus for handling gases, platinum ware, polarization apparatus, thermometers, etc. The catalogue is conveniently arranged in alphabetical order, and fully illustrated.

A prominent engineer of the POWER MINING & MACHINERY Co. gives the following interesting particulars concerning the economies of gas-generating plants, as compared with steam plants. The yearly records of eleven electric power stations, each serving a population of 5000 or less, and of forty-five stations, each serving 5000 or more, show:

The average B. H. P. developed, 1235.

The average coal consumption per B. H. P. hour, 5.5 lbs.

The average cost of coal per ton, \$4.30.

Cost of fuel in steam plant (operating 10 hours per day), 33.96 tons coal at \$4.30, \$146.02.

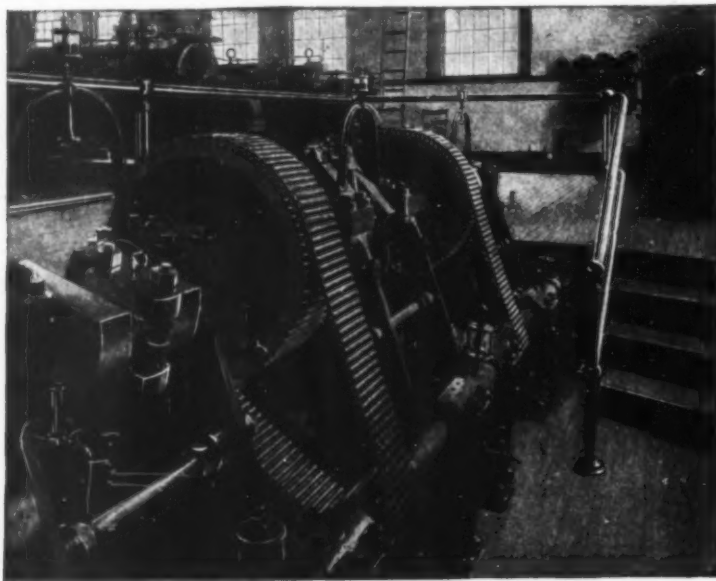
Cost of fuel with our gas engines and producers, 7.72 tons coal at \$4.30, \$33.19.

Saving per day, \$112.83.

Annual saving (365 days at \$112.83), \$41,182.95.

This would mean a saving of over 77 per cent for fuel alone, paying practically 11 per cent on the average capital invested in the above fifty-six plants. The producers of the Power & Mining Machinery Co. work on hard or soft coal, wood or coke, changes from one to the other being made without interruption.

USES OF LAVA.—We have received from the AMERICAN LAVA Co., Chattanooga, Tenn., an interesting pamphlet on lava for mechanical and industrial purposes. Lava is not, as is frequently supposed, a natural product of volcanic origin. It is the mineral talc, which is machined in its natural condition and then baked at a temperature of about 2000° F., to a condition of extreme hardness. It is then unaffected by any subsequent temperature short of that heat, and therefore by any heat to which it may be exposed when used in the construction of arc lamps, rheostats, electric heating apparatus, etc. It fuses with difficulty under a strong blast flame and, as the pamphlet states, "has no superior in withstanding the electric arc." It is only slowly dissolved by hydrochloric acid and is not affected at all by other acids or by alkali. It is absolutely free from metal oxides or other impurities which would impair its insulating value. "It is permanent in constitution and, being a natural product, is not subject to variations in structure or composition." It neither swells nor shrinks with



SILENT CHAIN DRIVE, APPLIED TO PUMPS

an electric power distributing system, the silent chain proves particularly applicable for machine driving. For this reason the subject should be of special interest to all metallurgical works with modern equipment.

ST. LOUIS EXPOSITION.

Owing to lack of space, we have to reserve for our next issue descriptions of several exhibits of interest to electrochemists and metallurgists, supplementary to our article in our September and previous issues.

A list of prizes awarded by the jury to exhibitors will also be given in our next issue.

INDUSTRIAL NOTES.

We have received from Mr. HUGH E. KING, Chicago, Ill., a pamphlet on the Pelton electric furnace for manufacturing jewelers, assayers, chemists and the tempering or hardening of steel hubs and dies. The standard types are for both direct or alternating current at 100 to 120 volts. The furnace is a muffle furnace with a large sheet of mica in the door, which affords unobstructed view of the interior of the muffle, thus enabling the operator to observe his work.

changes in atmospheric moisture, and its coefficient of expansion with temperature being negligibly small, it is of especial value in instruments requiring a fixed relation of their parts under all conditions. The material before baking is sawn, milled, drilled, turned and threaded with the same freedom as brass and by tools of the same character. Concerning its electric insulation capacity, it is stated to be remarkably uniform in its ability to withstand high potentials, even better than porcelain.

The NATIONAL ELECTROLYTIC Co., Buffalo, N. Y., is reported to have purchased the plant and business of the Vermillion Chemical Co., at Niagara Falls, N. Y. for \$600,000, and will continue the manufacture of electrochemical products, adding largely to the products turned out.

Dr. JULIUS KOEBIG and Mr. STEPHEN V. CHILDS have consolidated their chemical and metallurgical laboratories in Los Angeles, Cal., at 127 West First Street, where they have the best modern facilities for making tests by amalgamation, concentration and cyanide; for making chemical analyses and assays. Their establishment takes the name of the Los Angeles Chemical and Metallurgical Laboratories.

OBITUARY.

The sudden death of Dr. THOMAS M. DROWN, president of Lehigh University, will be felt by thousands of his friends and old students as a personal loss.

Thomas Messinger Drown was born March 19, 1842, and was educated at the Philadelphia Central High School, where he graduated in 1859. He then took up the study of medicine and three years later received the degree of M. D. from the University of Pennsylvania. After a brief period of practice as a physician, he turned to chemistry as his life work, and studied under Professors Brush and Johnson at Yale and under Professor Gibbs at Harvard. Three years were spent in Germany in the study of chemistry and metallurgy, partly at the School of Mines at Freiberg, and partly under Professor Bunsen at Heidelberg. He subsequently established himself as an analytical chemist at Philadelphia, and removed in 1874 to Easton, Pa., to become Professor of Chemistry at Lafayette College, where he remained for seven years. In 1873 he was elected secretary of the American Institute of Mining Engineers, and retained that position by unanimous re-election until he resigned it in 1883.

An episode from this period of his life characterizes the man, who, in a critical moment, when things were to be done, knew what to do. In June, 1879, Pardee Hall, of Lafayette College, then containing the office of the secretary, and the library and other possessions of the institute, was destroyed by fire. It was impossible to save much, so Dr. Drown immediately decided to sacrifice his own technical library and to save the records of the Institute and the stock of back volumes of the Transactions. In this he was successful.

In 1885 he accepted the professorship of chemistry at the Massachusetts Institute of Technology, where he built up a large and successful department, including, at the time of his resignation, twenty-one instructors and five hundred students. From 1887 to 1895 he was in charge of the chemical department of the investigation of the natural waters of Massachusetts. In 1890 he was appointed a member of the international committee to devise standard methods for the chemical analysis of iron and steel. He was elected an honorary member of the Institute of Mining Engineers, and in 1897 its president.

In the spring of 1895 Dr. Drown was elected president of Lehigh University, and on June 19th of that year he was inaugurated. How successful his administration has been for nearly ten years is a matter of common knowledge. He died suddenly, on November 16, from the effects of a surgical operation.

PERSONAL.

Dr. CHARLES BASKERVILLE, the new head of the department of chemistry in the College of the City of New York, has been presented with a loving cup, designed by Tiffany & Co., by his former colleagues and students at the University of North Carolina, on the occasion of the tenth anniversary of his doctorate.

According to a note of Mr. R. Pitaval in the *Journal de l'Electrolyse*, the Committee of Chemical Arts of the Société d'Encouragement pour l'Industrie Nationale has decided to grant the grand Lavoisier medal to Mr. P. L. T. HEROULT, the distinguished electrometallurgist of aluminium and iron and steel. The Society grants this medal every seven years to that inventor whose work has exercised the greatest influence on the progress of the French industries in the field of chemical arts during the past six years. The former Lavoisier medalists are Messrs. Osmond (1897), Solvay (1891) and Michel Perret (1885).

Mr. NEWCOMB CARLETON has been appointed fourth vice-president of the Westinghouse Electric & Mfg. Co. Mr. CARLETON was director of works at the Pan-American Exposition, and afterward vice-president of the Bell Telephone Company, of Buffalo. He will now have headquarters in the executive offices of the company at 120 Broadway, New York city. Mr. L. A. OSBORNE, formerly fourth vice-president of the company, has been promoted to the office of third vice-president, made vacant by the resignation of Mr. PH. FERD. KOBBE, who has retired from his more active duties on account of ill health. Mr. Kobbe will continue his membership on the board of directors, and the company will still have the advantage of his counsellorship in this capacity.

DIGEST OF U. S. PATENTS

PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,

National Union Building, Washington, D. C.

MOLTEN ELECTROLYTES, MISCELLANEOUS.

(Continued from page 474.)

507,374, October 24, 1893, F. M. Lyte, London, England.

A carbon electrode having a central bore filled with fusible metal, e. g., lead or tin, into which depends a terminal of copper or of iron coated with lead.

510,276, December 5, 1893, F. M. Lyte, London, England.

A cell for electrolyzing molten lead chloride, consisting of a pot of cast or wrought iron, and a bell of earthenware or plumbago, which depends into a layer of molten lead, serving as cathode, in the bottom of the pot. The space between the upper part of the pot and the bell is filled with powdered charcoal or sand, resting on the lead. A siphon tap for the lead extends through the side of the pot. Carbon anodes of the construction shown in the preceding patent, extend through the top of the bell, tight joints being made by means of asbestos string or a cement of ground asbestos and a sodium silicate. The bell has a feed pipe which extends down into the lead chloride and a chlorine outlet. The cathode connection may be a tinned iron rod extending into the lead outside the bell, or the pot may serve as the cathode if tinned internally.

473,393, April 19, 1892, Paul L. T. Heroult, Schaffhausen, Switzerland.

An anode for the electrolysis of molten compounds, especially of aluminium, consisting of small carbon slabs of regular shape, fitted together so as to break joints and held by

transverse pins or dowels of carbon, the metal to be recovered or an alloying metal. The slabs are clamped together by metallic side plates and bands.

503,429, August 15, 1893, Farnham M. and Cecil H. M. Lyte, London, England.

Simultaneously purifies lead, recovering the silver, and produces chlorin. Lead freed from zinc is oxidized and dissolved in nitric acid. Spongy or finely divided lead is added to the solution to precipitate the silver and other metallic impurities. The lead is then precipitated as chloride, which is washed, dried, melted and electrolyzed. The cell is a vessel of earthenware or enameled iron heated in a sand bath. The electrodes are depending alternate anode and cathode plates of graphite, passing through gas-tight joints in the cover. The cover is sealed by a liquid or an asbestos gasket, and has a chlorine outlet. The metallic lead collects in the bottom of the vessel and overflows through a siphon of earthenware or iron enameled externally. The lead chloride is introduced through a sealed pipe. The molten lead may be made the cathode. The lead is precipitated from the nitrate solution by calcium or magnesium chloride. These may be obtained from the waste chloride liquors of the ammonia-soda process, *e. g.*, a liquor containing calcium and sodium chloride may be concentrated by boiling and the sodium chloride crystallized out by cooling. Any lead retained in the residual calcium nitrate solution is precipitated by milk of lime, lead hydrate, magnesia or caustic soda. The calcium nitrate is evaporated to dryness and decomposed to recover the nitric acid. Magnesium chloride produced by treating magnesia with calcium chloride and carbon dioxide may be employed as a precipitant. The resulting magnesium nitrate is returned to give nitric acid in magnesia.

531,309, December 25, 1894, Alfred Guillaume, Chicago, Ill.

Ores containing, *e. g.*, lead, copper, zinc and silver are smelted by an electric arc, the temperature of the arc being gradually raised to remove the metals in succession, beginning with that of lowest melting point. The smelting furnace is a horizontal chamber with electrodes extending through the ends, the cathode being a bent, water-cooled carbon tube.

The temperature of the arc is regulated by a rheostat. The slag flows through a tap-hole onto a frusto-conical rotating horizontal drum cathode, cooled by water flowing through it. The metallic deposit is removed from the drum by a scraper. The electrolyzing current flows from the positive electrode of the smelting furnace through the slag to this cathode, but a separate anode may be employed. When gold or silver is to be electrodeposited on the drum, it is formed of an alloy of 95 copper and 5 aluminium; for the baser metals, of 95 steel and 5 aluminium.

537,005, April 9, 1895, George D. Burton, Boston, Mass.

Sulphide ores of gold and silver are smelted by carrying lumps of the ore down an inclined metal-plate cathode in a stream of an aqueous solution of sodium carbonate and borax, or cream of tartar and sodium chloride. The solution is pumped onto the higher end of the plate by a metallic bucket-wheel, serving as the anode. The ore is smelted by arcs formed around the lumps, a current of 100 to 300 amperes at 500 to 1000 volts being employed. The cathode plate rests on a hearth of firebrick. The molten products run from the lower end of the hearth through a screen into a water tank, from which the metals are recovered as globules. The cathode plate may be of lead, copper or iron.

559,729, May 5, 1896, Richard O. Lorenz, Gottingen, Germany.

Produces zinc and lead by leaching ores and waste with acetic acid to remove lead and silver, and with hydrochloric acid to remove zinc. Converts the lead and silver into chlorides. The zinc lyes are purified, evaporated to dryness, melted and electrolyzed. The cell is an inclined retort-like vessel of iron lined and coated with fire-clay. It has a clay cover with a gas-outlet and a tap-hole below. The carbon-rod anodes and cathodes pass through the cover. The electrolysis is

so conducted as to secure a frictional separation of the metals, silver being first deposited mixed with a certain proportion of lead, followed by lead and zinc. During the separation of the lead the potential difference is maintained at 0.4 to 0.5 volt, and during the separation of the zinc at 0.8 volt. Various substances may be added to modify as desired the melting point of the bath. The evolved chlorine is converted into hydrochloric acid by the joint action of carbon and steam at low red heat.

582,923, May 18, 1897, Alfred E. Hunt, Pittsburg, Pa.

A fusion pot, more particularly intended for the production of aluminium and designed to prevent accidents in cases where a large number of cells are connected in series. The pot is of the usual construction and constitutes the cathode, the anodes consisting of depending carbon rods. The bottom plate of the pot is extended outwardly to form a platform upon which the workman may stand while manipulating the anodes. This platform being at the same electrical potential as the pot itself, and the fall of potential between the anode and cathode of a single pot being but slight, there is no possibility of a serious shock to the workman.

587,830, Leon P. Hulin, Modane, France.

Compounds of the character of pumbates, chromates, anti-moniates, etc., are produced by the oxidation of metallic alloys. Lead, chromium, antimony, bismuth or manganese is alloyed with an alkali or alkali earth metal by fused bath electrolysis, and the alloy heated to dull red in contact with air, thereby forming the peroxide of the heavy metal and the protoxide of the alkali metal; the oxidized products are continuously removed and insoluble peroxide recovered by digestion in water. Specifically, electro-deposits sodium from sodium chloride into lead cathode, circulates the alloy to the point of oxidation, and returns the impoverished alloy to the electrodepositing crucible.

591,355, October 5, 1897, Henri Moissan, Paris, France.

Cast titanium, consisting of metallic titanium with two to six per cent of carbon, 96 parts to an arc of 1000—2000 amperes at 60—70 volts in a carbon crucible. The carbon may be in part removed by remelting the product with titanic oxide in an arc of the same character. If a greater proportion of carbon is used in the mixture, the product is titanium carbide, TiC , ($TiO_2 + 3C = TiC + 2CO$) a crystalline carbide having the color of galena and a specific gravity of 4.3. Titanium alloys are produced by carrying out the first-mentioned reduction in presence of iron or nickel, these alloys being useful for the manufacture of titanium steel. Alloys may also be prepared by fusing the alloying metal in the electric furnace and gradually adding agglomerates consisting of titanium oxide, carbon and a glutinous matter.

596,458, December 28, 1897, Walter E. Inglis, Mount Vernon, New York.

Reduction of tin oxide in presence of a fused electrolyte. A non-conducting crucible is provided with a cathode of molten tin on the bottom and superposed anodes of carbon, the electrolyte being molten sodium chloride at a temperature above the volatilizing point of sodium. The crushed ore is fed upon the cathode through a central tube, and is reduced in this tube by sodium vapor distilling from the cathode. As the reduced tin accumulates it overflows through the lower portion of the body of ore into a groove in the bottom of the crucible upon the cathode basin, any sodium contained in the tin being oxidized by this contact with tin ore. An electromotive force of five volts is used. Any silica which may be present is converted into a fusible silicate which is said to overlie the metal in the groove and to be tapped out with the metal.

602,575, April 19, 1898, Andrew Dickey, Niagara Falls, New York.

Aluminium reduction pots of the Hall type are provided with a tap fitted with a taper plug of wood or charcoal protected by clay from atmospheric oxidation.

